EFFECTS OF HUE, SATURATION, AND BRIGHTNESS ON ATTENTION AND PREFERENCE

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By

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September, 2000

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I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Ph.D. in Art, Design, and Architecture.

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ABSTRACT

EFFECTS OF HUE, SATURATION, AND BRIGHTNESS ON ATTENTION AND PREFERENCE

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Ph.D. in Art, Design, and Architecture

Supervisor: Assoc. Prof. Dr. Cengiz Yener

September, 2000

In order to investigate preference and attention responses for foreground-background color relationships, 123 university undergraduates in Ankara, Turkey, viewed 8 background colors on which color squares of differing hues, saturations, and brightnesses were presented. Subjects were asked to show the color square attracting the most attention, and the one they preferred on the presented background color. Findings on attention showed that on any background, colors of maximum saturation and brightness attract the most attention (67%). Yellow-green, green, cyan range (45%) attracts attention, followed by red, magenta range (30%). Findings on preference showed that colors having maximum saturation and brightness are most preferred (25%). Blue is the most preferred hue regardless of the background (25%). Foreground-background color relationships in terms of attention and preference are also included in the findings of the study.

Keywords: Color, Color Combinations, Color and Attention, Color Preference.

ÖZET

RENK TÜRÜ, DOYMUŞLUK, VE PARLAKLIĞIN DİKKAT ÇEKME VE TERCİH ÜZERİNDEKİ ETKİLERİ

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Renk-fon ilişkilerinin dikkat çekme ve tercih üzerindeki etkilerini araştırmak amacıyla Ankara'da eğitim gören 123 üniversite lisans öğrencisinden, 8 fon rengi üzerinde renk türleri, doymuşlukları, ve parlaklıkları değişen karelere bakmaları istenmiştir. Deneklere dikkatlerini en çok çeken kareyi ve gösterilen fon rengi üzerinde en çok tercih ettikleri kareyi göstermeleri söylenmiştir. Dikkat üzerine olan bulgular, tüm fon renklerinde en doymuş ve parlak karelerin seçildiklerini göstermiştir (%67). Sarı-yeşil, yeşil, camgöbeği mavi bölgesi (%45) ve kırmızı, çingene pembesi bölgesi (%30) dikkat çekici bulunmuştur. Tercih üzerine olan bulgular, en doymuş ve parlak karelerin tercih edildiklerini göstermiştir (%25). Mavi, fon renginden bağımsız, en çok tercih edilen renk türü olmuştur (%25). Çalışmaya renk-fon ilişkilerini dikkat çekme ve tercih açılarından irdeleyen bulgular da eklenmiştir.

Anahtar Sözcükler: Renk, Renk Birliktelikleri, Renk ve Dikkat Çekme, Renk Tercihleri.

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1 INTRODUCTION

1.1 PROBLEM STATEMENT

Color, in the everyday life of people who enjoy color vision, appears as a natural attribute of the sensed world. The sensations that color cause are usually taken for granted and the complexity of color sensation is not apparent at the first instance. Understanding color sensation is not easy as it can be attributed to various theories including biological factors, universal scale of preference existing in people, or unchanging stimulus qualities. Responses to color may be influenced by social and cultural factors.

Colors can be precisely specified by their hue, saturation, and brightness (value). These three attributes of color are sufficient to distinguish one color from all other possible perceived colors. The hue is the aspect of color usually associated with its name such as red, blue, yellow, etc. Saturation refers to relative purity. When a pure, vivid, strong shade of red is mixed with any amount of gray, weaker or paler reds are produced. All those produced reds will have the same hue, but different saturations. Brightness is associated with the total amount of light energy present in that color ("Colour"). The sensation of a single color may vary with a change in any one of the three attributes of that color. In other words, when saturation

and/or brightness and/or hue of a color change, the sensation of that color also changes.

Color may cause many visual sensations: signaling, intensifying, arousing, appealing, alluring, enhancing, deceiving etc. A single color in isolation may incite sensory responses but in actuality colors are rarely viewed in isolation. Color combinations involve more than one color stimulus perceived simultaneously. This occurrence may evoke visual sensations that differ from the ones caused by a single color stimulus. In this dissertation two groups of sensations, attention (signaling, intensifying, arousing, etc.) and preference (appealing, alluring, enhancing, etc.) are explored. The intention of this dissertation is to explore effects of hue, saturation, and brightness on attention and preference of colors presented on colored backgrounds.

Within a controlled experimental setup, 123 undergraduate students studying in art/design related departments were presented image sets through a computer monitor. The image sets consisted of 8 background colors selected from HSB (Hue, Saturation, Brightness) color space (see sec. 5.4.1). Each image consisted of a background color and 63 color squares of differing hues, saturations, and brightnesses. Details of the experimental setup are included in chapter 5. Every subject viewed and answered the two experiment questions for the eight background colors. The two questions of the study were:

1. Which color square attracts the most attention and,
2. Which color square is preferred by the subjects,

on the presented background colors.

Several research objectives are pursued through the course of this inquiry. The first objective is to determine the effect of the three attributes of color (hue, saturation, brightness) on the choices on colored backgrounds. The second objective is to explore whether background colors have an effect on the choices. The third objective is to investigate whether there is an effect of the location of a color square on the choices. The fourth and the final objective is to determine how gender influence the choices for attention and preference.

Attention is a condition of readiness for a selective narrowing or focusing of consciousness and receptivity ("Attention," def. 1b). Visual attention is the selective response of the eye. The main function of attention is to decide which information will be selected for high priority processing. As far as vision is concerned it is impossible for people to recognize every object in every region of their visual field at one time. The visual system accomplishes object recognition by selectively gazing on a relevant (or salient) portion of image or region (Hsieh 2). Thus, only the information within this portion is processed, and then the visual system moves on to another relevant portion. In the context of this explanation, attention may be used in the same way as selectivity. Selectivity may occur in two ways: stimulus-driven or goal-directed. In stimulus-driven, selection is determined by the properties of the stimulus itself even if they are irrelevant to the current task.

In goal-directed, observers' knowledge and goals determine what to select (Hsieh 1-4). The initial goal of the research was to detect stimulus-driven attention of the viewers by recording their eye-movements. The underlying hypothesis was that certain color squares presented would be able to provoke a strong enough stimulus so that the viewer unintentionally would look at that color square. The eye-movement recordings showed that the viewers scanned the image presented briefly and than lost interest in it, staring continuously towards the screen. When they were asked the reason for their continuous non-moving staring towards the screen, they responded that the images presented were *only* various colored squares of the same size on a colored background. As they understood the pattern through quick scan, they have lost interest in it. For that reason, the research questions were presented before the images were shown, and the subjects made visual comparisons in order to answer the questions. Thus, the final experiment concentrated on goal-directed attention.

To prefer is to like better or best. Preference is the one that is preferred ("Prefer," def. 2; "Preference," def. 2). In this dissertation the term "preference" was used synonymous with "pleasantness" and "appeal," in the sense that the color square which "suited most to" or "looked good on" the background color were sought by the subjects. Preference, pleasantness, and appeal, all suggest subjectiveness. Although preference is to some extent specific to individuals, there are many questions surrounding the complexity of the issue. The extent to which preferences on color combinations reflect personal "taste," reflect culture, are universal or

biological, and are influenced by fashion trends at the time, are all unanswered issues at hand.

Color is an inherent property of materials and an inseparable component in decisions considering product or building design. The color of materials is functionally important, as it is often essential that the object be discriminated from its background in a proper way to enhance the design intention. From the point of view of the manufacturer of a product or a building developer, it is equally important that the colors of the materials do not have a negative impact on those who interact with their products. They would also like to take advantage of any positive impacts that the choice of the color of materials might have. For this reason, there has been long and continuing interest on the part of manufacturers, advertisers, product developers, and designers in the question of color preferences and aesthetics.

The use of color in design has been two fold. On the one hand there has been scientific research from the fields of physics, psychophysics, and psychology. Information gathered and reviewed from these fields has been overestimated sometimes, and was used in applications in an uncritical manner. On the other hand, there have been theories developed for centuries by experiences of artists and/or designers. The latter is traditionally referred to in design and art education. *Expert views*, as it is designated in this study, are also found to be convenient as the formulas provided have been *applied and tested before* by an admirable artist or designer. It should be noted that expert views do not have to depend on any

empirical research and that experimental research comparing its findings with those expert views are few.

The multifacetness of issues concerning color only allows slow and limited progress in terms of experimental research. Though it may seem limited because of the controlled setup of the experimentation, this dissertation attempts to advance our understanding of color in attention and preference.

Human perception is still an uncovered area and much work has to be done in finding an answer to the phenomenon. Any contribution in this field is important, as there is a very complex problem at hand. The experiment conducted in this dissertation is very restricted and well-defined in its setting, which was necessary to control the variables and to gain an understanding of aspects of attention and preference in color perception. Through a review of pertinent literature and analyses of the empirical data of this research, answers to the research questions and objectives were sought.

1.2 OUTLINE OF THE STUDY

This research mainly focuses on two issues: attention and preference. Each one of these issues has been treated in the same manner. The general approach is, first to review previous studies on the specified topic, then to present the experimental setup, and finally to supply a detailed analysis of the findings with a discussion comparing the findings with previous studies.

A review entitled "Color Basics" on basic definitions is included at the beginning. This chapter is a critical review of basic definitions, including color, brightness and lightness, color systems, and contrast.

This review is followed by literature review, consisting of four parts. The first part discusses experimental studies that treated color in isolation. The second part examines experimental studies, which have concentrated on color combinations. The third part looks into other studies on the issue, and the last part is a summary of implications that may be derived from the review of the studies in that chapter. The chapters on literature review are entitled "Color and Attention" and "Color and Preference," respectively.

The literature review is followed by a detailed explanation of the experimental research in this study, and covers the hypotheses, the experimental setup, the equipment, and the image sets that are used.

A chapter entitled "Data Analysis" follows, where experimental data is analyzed with appropriate statistical methods and presented in detail for each of the topics, attention and preference. The findings are summarized and compared with the available literature under the chapter heading: "Discussion of the Findings."

All visual and written material involved in the experiment, the data structure used in statistical analysis, and full results of the statistical analysis are included in the appendices.

2 COLOR BASICS

2.1 COLOR: A DEFINITION

Color is a complex term embodying many connotations. Although in everyday life, the word "color" is used without any confusion and complexity involved, trying to define it requires perspectives from different disciplines. Color is an electromagnetic radiant energy providing "a physical stimulus that enters the eye and causes the sensation of color" (Kaufman 5-1). "A color stimulus is radiant power of given magnitude and spectral composition, entering the eye and producing a sensation of color," wrote Stiles and Wyszecki, providing a similar definition (723). Although these definitions provide all the information needed, the question remains: "What is color?" Elaborating the question, one may ask whether an object has color because of its physical-chemical composition or whether illumination constitutes the color of the object.

The color of an object, or *object color*, is the color of light reflected from or transmitted through an object when it is illuminated by a standard light source, which is white (relatively balanced in all visible wavelengths) and has a continuous spectrum (Kaufman 5-2).

The color of light, or *source color*, is radiant power at various wavelengths of the visually effective spectrum, which is considered to extend approximately from 380 to 780 nm. Identical colors of light are produced not only by identical spectral power distributions, but also by many different spectral power distributions depending upon their relative visual effectiveness. Different spectral power distributions having the same sensation on the retina are called metamers. Associating "color" with "light" requires further evaluation in order to make the definitions of "white light" and "colored light" distinguishable. Nuckolls elucidates this issue:

> If white light is described as visible radiant energy that is relatively balanced in all the visible wavelengths, then it follows that color is an imbalance of visible radiant energy reaching the eye from light sources or objects. A colored light source radiates more energy at some wavelengths than at others. It follows that a colored object reflects or transmits some wavelengths more easily than others. In both cases, there is an energy imbalance. (32)

The phenomenon that occurs when an object is viewed under a light source other than a white one (having a continual spectrum balanced in all visible wavelengths), is *perceiving a color as belonging to that object*. The perceived object color is something that is perceived instantaneously. It is a very common experience in everyday life. Thus, a perceived object color should also be considered besides the already mentioned object color and source color (color of light).

Despite its simplicity in experience, color perception results from the interactions of many complex factors like: the characteristics of the object, the incident light

and the surroundings, the viewing direction, observer characteristics, observer adaptation, etc. Including the observer into the process (not separable from the phenomenon of perception), also brings forward some other factors like: time of seeing, what was seen last, how attention was focused in relation to time of seeing, etc.

In defining color, three understandings come forth: the color of source (light), the color of objects, and the color perceived. Evans exemplifies the everyday experience of color with the use of the above terms as:

> It is entirely reasonable in common speech to refer to the light from a "white" source, passing through a "yellow" transparent substance, falling on a "purple" object, and being seen as "red." [. . .] The words refer to different aspects of the subject and imply vision under different conditions. (*Introd. to Col.* 2)

Apposed to these different experiences in viewing color, three distinct fields of research (physics, psychophysics, and psychology) explicate color in differing manners. Color, in physics, is wavelength; in psychophysics, it is wavelength modified by the sensitivity of the average observer (spectral sensitivity curve); in psychology, it is the personal perception of the object.

Physics is interested in the light that enters the eye, which enables people to see their environment. The properties and characteristics of this light can be measured and explained without taking the eye into consideration. The measurements and specifications that fall into the realm of physics are completely determinable by

methods that are repeatable and do not require the light to be seen. Thus, the physicist can state with certainty that two beams of light are identical, or how two beams differ. On the other hand, he cannot state how the two will look. Physics deals with the quality and quantity of light without any reference to any observer (Evans *Introd. to Col.* 4).

The realm of psychophysics studies the reaction of the visual mechanism under a given, fully specified set of conditions. It is possible to calculate whether two beams of light look alike to a person with well-defined "average normal" vision. If they differ, the difference in appearance cannot be calculated, but can be evaluated in terms of the known properties of the eye. Thus, it is possible to state that two differences are of the same magnitude, although it is not possible to determine the appearance of the difference. Psychophysics studies the relative evaluation of light beams with respect to normal observers under standardized conditions (Evans *Introd. to Col.* 5).

The field of psychology deals with the ways in which light may affect the consciousness. It largely deals with mental responses and the conditions under which these responses operate. It studies the relationship between the colors as calculated for the standard observer and the color actually perceived by the mind. This includes factors like attention, attitude, feeling, etc. It is the study of the effect on the observer produced by the conditions, which differs from the predictions based on the eye considered as a standardized mechanism (Evans *Introd. to Col.* 5).

The system of nomenclature developed by the Committee on Colorimetry of the Optical Society of America (OSA), provides useful verbal distinctions in between the fields of physics, psychophysics, and psychology in the realm of studies on light and color in table 2.1.

Table 2.1

OSA Nomenclature as Given by the Committee on Colorimetry.

Physics	**Psychophysics**	**Psychology**	
Visual stimulus	Light	Visual sensation	Visual perception
Radiant energy Spectral composition	Luminous energy Color	Color sensation	
Characteristics of radiant energy:	Characteristics of light = color:	Attributes of color sensation:	Corresponding modes of appearance:
Radiant flux a. Radiance b. Irradiance c. Radiant reflectance d. Radiant transmittance	1. Luminous flux a. Luminance b. Illuminance c. Luminous reflectance d. Luminous transmittance	1. Brightness	Aperture Illuminant Illumination Object modes: Surface Volume
Spectral distribution (Relative spectral composition, quality) Radiant purity	Chromaticity 2. Dominant wavelength (or complementary) 3. Purity	Chromaticness 2. Hue 3. Saturation	Attributes of modes of appearance: 1. Brightness (or lightness) 2. Hue 3. Saturation 4. Size 5. Shape 6. Location 7. Flicker 8. Sparkle 9. Transparency 10. Glossiness 11. Luster

Source: *Journal of the Optical Society of America* 33 (1943): 552, qtd. in Evans *Introd. to Col.* 6.

In this dissertation, in order to clarify any further confusion, the term *color stimulus* (or simply *stimulus*) will be used to refer to the light that arrives at the retina. The term *color response* (or simply *response*) will be used to refer to the perception of a color by the brain.

Quantitative schemes like CIE (Commission Internationale d'Eclairage) Color Space or Munsell System are based on human observation under the broader topic of psychophysics. Agoston describes the rationale of the psychophysical approach in a simplified manner as follows:

> Light enters the eye and is absorbed by the retina. A series of events is caused to occur that lead to the production of a signal or sensation in the brain. The sensation makes us aware of a characteristic of the light. Color is this characteristic. (Note that color is not a sensation.) Alternatively and equivalently, color is the characteristic of materials that results in their changing the characteristic of the illuminating light. (9)

A similar explanation is provided by Nuckolls:

> [. . .] the normal eye receives the visible spectrum, creates a chemical reaction in certain cells that send electrical impulses through a group of nerves that connect to the optic nerve, and finally passes these impulses on to the brain. (32)

In more technical terms, the characteristic (color) of the light is its spectral power distribution (wavelength composition), while the characteristic (color) of an opaque material is its spectral reflectance distribution that has to be considered together with the characteristic (color) of the light illuminating the material. Color,

characterized in both of the above ways can be defined as numerical data or graphical data. Thus, color is a characteristic of the stimulus (the visible radiant energy in the range from 380 to 780 nm) and is a part of the radiant energy that reaches the eye of a standard observer who has typical normal color vision and is aware through the agency of his eyes and the associated nervous system of this radiant energy, making typical use of the radiation that produces vision.

2.2 BRIGHTNESS AND LIGHTNESS

Brightness and lightness have always been problematic terms to define and explain, in the fields of lighting and color research, due to their dependence on human psychology as much as human psychophysics and physics of light. Although the CEI (International Electrotechnical Commission), which is one of the most reliable sources of information stated in 1987 in its vocabulary list, the term "brightness," as obsolete, in the author's view it still conveys useful insights into the phenomenon of visual perception of our environment (51). Lightness, on the other hand, also requires attention due to the fact that it is easily confused with brightness, and being synonymous with "value" which is used as one of the variables in defining color within the Munsell Color System.

CEI's, *International Electrotechnical Vocabulary* defines brightness as an obsolete term synonymous with luminosity, "an area appearing to emit more or less light" (51). Evans provides another definition of brightness, linking it to human psychology, "(brightness is) [. . .] the mental evaluation of the light by an *actual*

observer" (*Introd. to Col.* 39). He explains the term further by saying, "(brightness is) [. . .] the mental reaction *produced* by the light and so is properly described as the *apparent* luminance of the light" (*Introd. to Col.* 159). There are two main considerations in this definition: brightness being a mental reaction (apparent brightness) and its cause being luminance (measured brightness).

In physical terms, the light coming from a source is the radiant flux; in psychophysical terms light that affects the eye while looking at an object or at a source is the luminance. Finally, the affect of light leaving an illuminated object or a source passing through the eye and evaluated in the brain is brightness in psychological terms.

Luminance is the effectiveness (effective intensity) of a given light *on the eye* regardless of its origin. In its most general sense it can be thought as the energy at each wavelength multiplied by the sensitivity of the eye to that wavelength. Luminance is a measurable variable and is based on the luminous efficiency. Evans defines brightness in *Perception of Color* as "the perception of the general absolute luminance level of the combined stimuli visible to the observer. It correlates with this luminance level always, in the sense that increasing it (luminance) would make the scene look brighter and decreasing it would make it appear less bright" (96).

The correlation between luminance and brightness does not really exceed the statement above, in the sense that increasing luminance causes a stimulus to be perceived "brighter" and vice versa. There are no formulas or calculable values to

determine on a scale how much luminance would cause a sensed amount of brightness. More interestingly, two isolated monochromatic stimuli of different wavelengths, but the same luminance may not appear equally bright.[1] Also, two equal brightnesses do not necessarily correspond to equal luminances. Equality of two brightnesses has no other meaning than that those two lights have equal *psychological* intensities. At this stage it is important to make a distinction between terms "lightness" and "brightness" as they are used interchangeably in many references, but have been defined as clearly distinguishable by Evans, Erhardt, and Agoston.

Evans defines "lightness" as the "mental perception of reflectance" (159), while he defines "brightness" as the mental perception of luminance. Evans continues to explain "lightness" by referring to OSA nomenclature as "[. . .] the visually apparent reflectance of a surface under a given set of conditions" (*Introd. to Col.* 119). Thus, it is possible to define "brightness" as a perceptible variable changing between the ranges of invisible to dazzling and which is dependent in a not measurable way to luminance (cd/m^2). "Lightness" is also a perceptual variable, which changes between the ranges of black and white and is dependent on reflectance or transmittance (%). It is important to note that brightness and lightness are perceptual variables and have no absolute measure. Luminance and reflectance (transmittance), on the other hand, are measurable psychophysical and

[1] Evans states, "[. . .] a high purity blue stimulus appears much "brighter" than a corresponding stimulus of longer wavelength" (*Percept. of Col.* 74).

physical variables respectively. Erhardt defines luminance and reflectance (transmittance) as follows:

> Luminance refers to the effectiveness on the eye of the light coming from a surface when both its illumination and reflectance are considered. [. . .] Reflectance is the ratio of the luminance of the reflected light *from* a surface to the illuminance of the light falling *on* the surface. Reflectance is often expressed as a percentage. (20)

Defining luminance and reflectance (transmittance) depending on each other is an outcome of the well-known formula of:

Luminance = Illuminance X Reflectance (or Transmittance)

It is important to avoid any confusion on the dependence of those two terms. It should be kept in mind that luminance is measured in cd/m^2, while reflectance (transmittance) is a ratio in percentages. Thus, if luminance is increased, as the surface is kept to be the same, its reflectance (transmittance) will be the same in ratio. Evans in *Introd. to Col.* alternatively explains psychophysical reflectance through the following formula (158):

$$\frac{\text{[(Energy of the light source at a certain wavelength) X (Percentage of light of that wavelength reflected from the surface) X (Sensitivity of the eye for that wavelength)]}}{\text{[Effectiveness of the light falling on the surface (Illuminance), evaluated with respect to the eye]}}$$

The sensitivity of the eye for a certain wavelength is a calculable parameter as the eye here is considered as a standardized receptor in terms of psychophysics. Reflectance, then, "[. . .] is a property of the *surface*, which varies with the energy distribution of the light source (i.e., a "red" surface has low reflectance to blue and

green light but high to red light, etc.)" (Evans *Introd. to Col.* 158). It is also important to note that gray surfaces are independent of the color of the light in terms of reflectance as they reflect the same percentage at all wavelengths. Reflectance is a characteristic of the surface for a certain light. Luminance is a characteristic of the light itself.

Going back to the previous discussion, lightness refers to the apparent relative reflectance or transmittance of a stimulus considered as a reflecting or transmitting object regardless of its physical nature. Lightness being a psychological variable, equal lightness can only be interpreted as having "[. . .] the same psychological effectiveness from the standpoint of the property of the surface called reflectance." (Evans *Introd. to Col.* 159). Thus, two surfaces of equal lightness do not necessarily actually have the same reflectance (or transmittance), and similarly two surfaces equal by physical and psychophysical calculations of reflectance (or transmittance) may not have the same lightness.

A better known word for "lightness" designated by the Munsell Color System is "value." Each step of the Munsell value scale has a numerical expression in terms of its reflectance or transmittance (percentages) and luminance (cd/m^2) (see table 2.2).

Table 2.2

Relation between Munsell Values (when illuminated uniformly to 1076 lux) and Reflectance (R, %) or Luminance (L, cd/m^2).

Value	0	1	2	3	4	5	6	7	8	9	10
R	0	1.2	3.0	6.4	11.7	19.3	29.3	42.0	56.6	76.7	100
L	0	4	10	22	40	66	100	144	194	263	343

Source: Adopted from Erhardt, 20.

Agoston briefly expresses the actual relation between Munsell value and perceived lightness:

> Formerly, uniform steps of Value in the *Munsell Book of Color* were established by visual means. But, because observers often fail to agree in comparing the lightness of color samples at high Chroma, an OSA committee decided to define Value by a mathematical formula that relates it to luminance factor, which is based on data that can be measured accurately. Nevertheless, Munsell Value defined precisely in this way does not represent perceived lightness accurately. For example, at a given level of Value, the perceived lightness increases as the Chroma increases. (121)

Although the problem of the incomparability of perceived lightness and calculated value of Munsell chips is of importance, in many references the word "lightness" is often defined and used synonymous with "value" in the Munsell sense.

The two terms, brightness and lightness, signify different physical and psychophysical affects on visual perception. Erhardt describes the distinction with a simple experiment:

> Consider a Munsell gray scale or value scale with uniform illumination and, therefore, a luminance pattern based solely on the reflectivity of each of the 10 steps. One has no difficulty in accepting that each of the steps differs from the next adjacent by an apparently equal amount, since that is the way the steps were constructed. Now move the light source to the dark side of the scale and arrange the individual parts of the scale in such a manner that each reflects the same number of lumens, so all have the same luminance. The gray scale appears substantially unchanged. Lightness varies from black to white despite the fact that the luminances are identical [. . .] The luminance of black in sunlight may be 4000 times as great as white in moonlight, but, again, black remains black and white, white. (20)

In much of the literature, brightness and lightness are used in the same sense, signifying mainly the Munsell value. Evans points out that "[. . .] brightness and lightness differ whenever there is a noticeable non-uniformity in the illumination of a scene" (*Introd. to Col.* 119) and then, he uses the two terms interchangeably. Similarly Agoston states conditions for using lightness and brightness in the same meaning as being applicable only when the object is isolated and the light coming to the eye from the object and from nowhere else (14). The terminology of the Optical Society of America (OSA) also defines color by three mental variables being: hue, saturation, and brightness (Evans 118). Thus, attributing the meaning of value to brightness.

2.3 COLOR SYSTEMS

Color systems are necessary to identify color in a systematic manner. In this section CIE, CIELUV, CIELAB, and HSB color spaces will be explained. CIE Color Space is very widely used in developing software programs related to the

usage of color. CIELUV and CIELAB are later versions of CIE Color Space, which are developed to provide a more uniform color space. The *Adobe Photoshop* software used in the experimental phase of this dissertation is based on CIE Color Space (see sec. 5.4). The *Adobe Photoshop* provides an automatic converter of color systems within its color picker function. As all the previous literature on color studies preferred to use hue, saturation, brightness (HSB) to define a color, it was found convenient to use the same terminology (see ch. 3; ch. 4; sec. 5.4). Thus, the HSB Color System is also explained in this section.

CIE Color Space is an internationally accepted method developed by the Commission Internationale d'Eclairage (CIE) in order to specify color (see fig. 2.1; fig. 2.2). It is based on a system where relative amounts of three standard primary colors (red, green, blue) are mixed to identify and specify any color. Equations that are developed to obtain colors from a mixture of relative amounts of primary colors are also transferred to a simple graphical representation (see fig. 2.3). This graphic representation serves many purposes including: a basis for selecting the

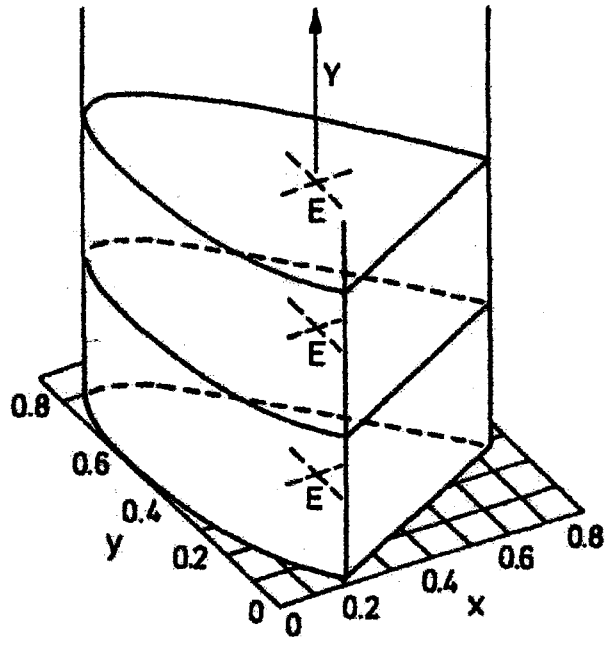

Fig. 2.1 CIE 1931 (*x, y, Y*) Color Space for Light Emitted by Luminous Objects (Agoston 106).

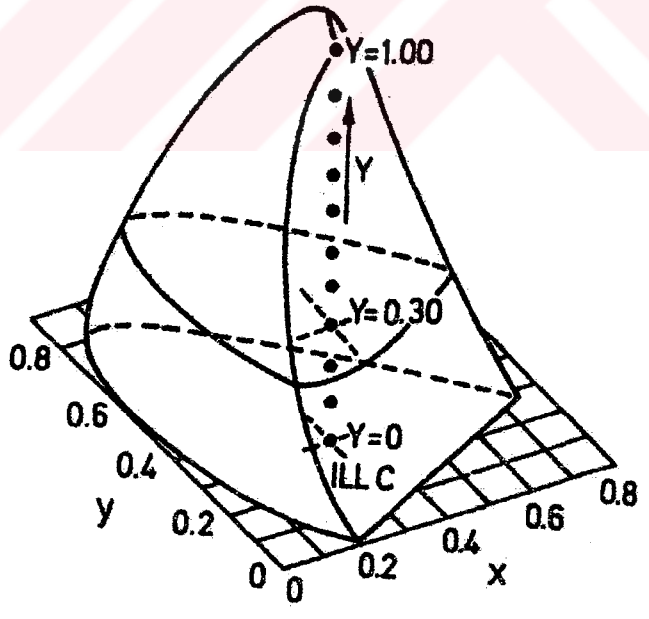

Fig. 2.2 CIE 1931 (*x, y, Y*) Color Space for Light Reflected from/Transmitted through Non-fluorescent, Non-luminous Objects (Agoston 106).

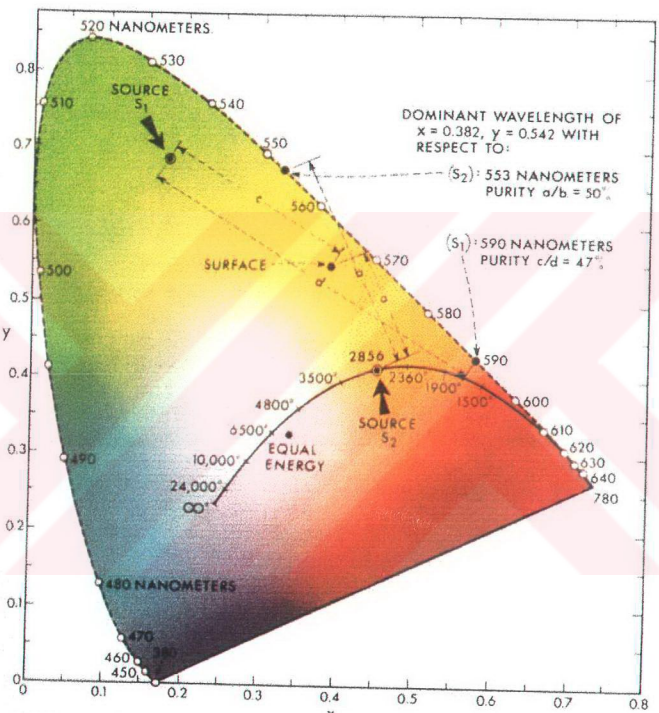

Fig. 2.3 Locus of Spectrum Colors on 1931 CIE Chromaticity Diagram (Kaufman 5-9).

color names for lights, prediction of the colors obtainable when two or more lights of known colors are mixed (light mixing), determining the color quality (hue and purity) when paints are mixed (paint mixing) or the color of a paint film that fades with time, selection of additive complementary colors, indicating the upper purity limits for colors of non-fluorescent pigments and dyes, etc. There are means and methods to convert various color spaces into CIE scheme, which provides a greater flexibility in its usage.

CIELUV and CIELAB color spaces were developed to approximate a uniform color space. The CIE 1960 (u, v) chromaticity diagram presented a starting point for the CIE 1964 (U^* V^* W^*) uniform color space. In 1976, a modification of this color space was adopted and called the CIELUV 1976 Color Space. The CIE 1976 (u', v') chromaticity diagram, associated with CIELUV Color Space was adopted around the same time. In the same year as CIELUV was established, an alternative color space, CIELAB 1976 Color Space, was also introduced. CIELAB was developed to correspond the ANLAB (40) color-difference formula[2]. CIELAB 1976 is also referred as CIE 1976 (L^* a^* b^*) Color System. One important aspect of CIELAB 1976 Color Space is that some very dark colors and black are excluded from it.

The CIELUV and CIELAB color spaces are only approximations to uniform color space. A perfectly uniform color space may not be attainable in a three-dimensional

[2] The ANLAB (40) color difference formula was widely accepted at the time, especially in the Great Britain, for the industries like textile, paint, and plastics (Agoston 90).

Euclidean model, but studies towards the development of a uniform color space and accompanying formulas that give substantially better correlation with visual judgments, continue.

HSB (Hue, Saturation, Brightness) is a psychological color specification system devised by Hurvich and Jameson (416-21). It specifies quantitatively the perceived colors of lights and of objects using three psychological parameters: hue coefficient, saturation coefficient, and metric lightness. The hue coefficient is the relative amount of one hue contained in a binary hue divided by the sum of the relative amounts of both hues. The relative amounts of the hues can be read from the chromatic response functions diagram in figure 2.4.[3] The saturation coefficient for spectral lights is attained by dividing the sum of the relative amounts of both hues in a binary hue by the sum of the relative amounts of both hues and the white component.[4] Hurvich and Jameson claim, "any real stimulus that elicits a chromatic response always elicits a simultaneous response in the achromatic visual process" (qtd. in Agoston 185). Thus, neither the saturation coefficient nor the perceived saturation can be 100%.

---

[3] The coefficient of the 460-nm spectral light, which has a hue coefficient 0.74 (or 74%) for blue, is obtained by dividing $|-0.64|$ (blue) by the sum $|-0.64|$ (blue) and 0.23 (red) (Agoston 184).

[4] Following examples from Agoston, the saturation coefficient for 460-nm spectral light is found 0.94 (or 94%) by dividing the sum of the relative amounts of the hues (0.87) by the sum of the relative amounts of the hues and of the white component (0.87 + 0.06) (Agoston 185).

In determining the hue and saturation coefficients for the colors of illuminated objects, the HSB system uses the chromatic response functions (see fig. 2.4). It may be of importance to note that, the CIE color specification uses the tristimulus values that are based on color-matching functions or tables that are derived from the HSB chromatic response functions.

The third variable, metric lightness L^*, is used both for the colors of non-luminous and luminous objects. This variable is defined same as the CIE (1976) lightness function, L^*.

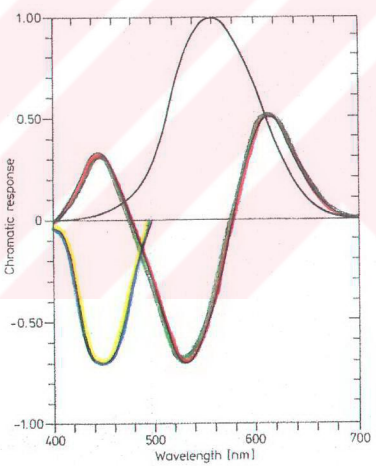

Fig. 2.4 Chromatic Response Functions (red/green, yellow/blue) and the Achromatic Response Function (black line) (Agoston 262).

The HSB System consists of brightness (for lights) or lightness (for objects) measured in equal perceptual steps along the vertical axis, and a circular psychological color diagram (HSB color diagram) on the horizontal plane. The equally spaced concentric circles represent lines of constant saturation coefficient, *S*. Radial lines from the center, are lines of constant hue coefficient (see fig. 2.5). The hue circle consists of four quadrants of unitary red, yellow, green, and blue. Each quadrant is subdivided into equal steps of hue coefficient.

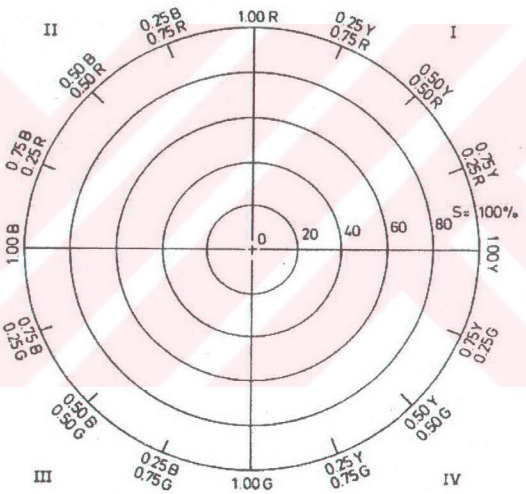

Fig. 2.5 HSB Color Diagram (Agoston 186).

The superimposition of the points for spectral lights at various wavelength intervals from 400 nm to 650 nm, on the HSB hue circle is shown in figure 2.6. Colors that differ equally in wavelength may not necessarily differ in their hues and saturations

in an equal manner. These variations are due to the sensitivity of the visual system to wavelength changes and to the ability of the eye to discriminate wavelengths in different ranges.

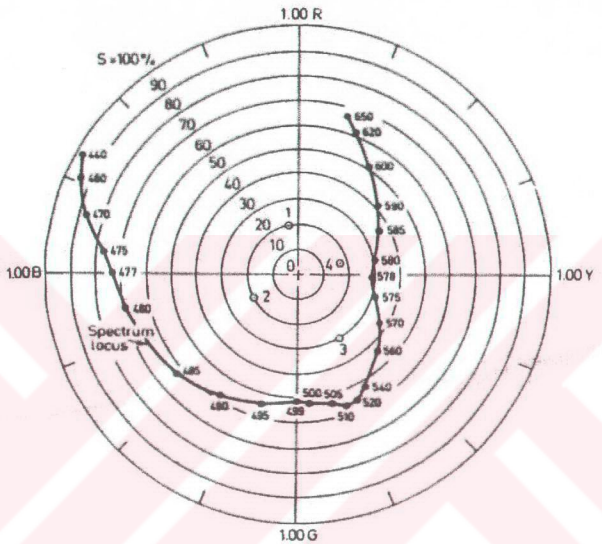

Fig. 2.6 HSB Color Diagram Showing the Spectrum Locus (Agoston 187).

The HSB system is not widely adopted for the specification of color. The CIE (*x*, *y*, *Y*) system is used more broadly in industrial applications.

2.4 CONTRAST

2.4.1 DEFINING CONTRAST

In everyday experience, contrast is a comparison that emphasizes differences. Seeing detail and transmitting information are mediated in the visual world by contrast. In the literature, there is a conventional differentiation between luminance contrast and color (chromatic) contrast. The definition provided by Kaufman is as follows:

> An object may be differentiated from its background because it differs either in luminance or in color; that is, there may be either a luminance contrast or a chromatic contrast (the term "luminance" is used instead of "brightness" because most objects are measured with photoelectric photometers today). Except in the case of self-luminous objects, both types of contrast are a function of the reflectance properties of the scene and of the incident illumination. (3-14)

Although luminance contrast is closely related to different incident lights falling upon two adjacent tasks, contrast may still be perceptible when the incident light for the two tasks is kept the same. The latter is an outcome of chromatic information. As all differing wavelengths have reflectances (or transmittances) of their own, the contrast arising from seeing two adjacent tasks under the same illumination is the contrast inherent in the reflectance (or transmittance) of those colors. Visual tasks having the same luminance with their background may still be discerned by color information. Thus, two colors of the same reflectance (transmittance) or luminance (or the same Munsell value) may still be

differentiable. This is called chromatic contrast and it is usually less distinct than luminance contrast. In this case the color attribute of saturation enables the contrast detection. In a rough manner it can be said "[. . .] the larger the difference in saturation between the target and the background, the larger the discrepancy between the perceived contrast and the estimated contrast based only on achromatic luminance" (Kaufman 3-15).

2.4.2 CONTRAST PERCEPTION

Contrast detection is the basic visual task from which all other visual behaviors are derived. The human visual system gives virtually no useful information unless there is a contrast in the retina (thus, also in the environment that is being viewed). The eye is not very sensitive in determining the intensities or intensity changes of uniform illuminations, but conversely, it is very sensitive to inform about luminous changes, luminous discontinuities, and gradients in the visual field. A small object, or a patch can only be seen on a larger one if the two differ in luminosity or in color, or differ both in luminosity and color. These differences are known as contrast.

Contrast is the main effect that enables human beings to see, more specifically to differentiate a visual task from its surroundings. Although contrast is well-defined in the realms of physics and psychophysics, there are psychological effects that should also be mentioned. Padgham and Saunders talk about an in-built mechanism in the eye for increasing the perceived contrast (37-38). The mechanism by which

the contrast is increased is explained by them due to lateral enhancement and inhibition mediated by the cross connections between neurons in the retina which can influence the perception in adjacent areas. They also relate the phenomenon to the differences of interpretation in the brain.

Sensation of color, or interpretation of color in the brain, is not only effected by adjacent areas of the stimulus, but also by the light under which the stimulus is seen. Two examples of this are the Helson-Judd effect and the Bezold-Brücke hue shift. The Helson-Judd effect is the tendency of lighter achromatic surfaces to take on the hue of the illuminant under which they are viewed and darker achromatic surfaces to take on the complementary hue. The Bezold-Brücke hue shift is a shift in the apparent color of a stimulus towards yellow or blue with the increasing intensity of light. If a pair of long wavelength lights differing only in intensity are compared, the higher intensity stimulus will look more yellow and less red than the lower intensity light. For shorter wavelengths, higher intensity lights look more blue and less green than lower intensity lights.

Contrast perception also causes visual effects that lead to variance in color sensation. This may be caused by either the psychophysics of the eye or by the interpretation of the brain. These effects are: successive contrast, simultaneous contrast, edge contrast, and assimilation (reversed contrast).

Successive contrast is the phenomenon where the intensity or chromaticity of an area of the visual field is modified by the preceding stimulus (Williamson and

Cummins 331). When eyes are fixed on a colored patch in a painting for a sufficient period of time and then they are moved on to another patch of a different color, it is likely that the image of the first patch is perceived upon the image of the second. This phenomenon, successive contrast, is mainly caused by the variation of the response of the visual system with time.

Simultaneous contrast is the phenomenon where the visual intensity or chromaticity of part of the visual field is modified by the intensity or chromaticity of adjacent areas (Williamson and Cummins 331). One of the most common experiments for the phenomenon is fixing the eyes on a square neutral gray patch at the center of a green area. With a green surrounding, the neutral gray patch looks reddish. As it is difficult to control the motion of eyes in normal viewing, the occurrence of simultaneous contrast might include an afterimage contribution from the previous stimulation. Simultaneous contrast is also known as spatial contrast. The changes in perceiving colors while there is simultaneous contrast are not usually noticed, especially when there is a relatively large background. If two different color patches of equal size are placed side by side, both will exhibit changes in color appearance. When the patches are separated, the changes decrease and eventually diminish, as the distance between them is increased.

Simultaneous contrast effects the hue changes by roughly superimposing the complementary color of the background on the foreground patch. This hue change is accompanied by changes in the perceived saturation depending on the afterimage complementary color produced. For example if a blue-green patch is viewed

against a red background, the patch will be perceived as blue-green again, but with an increased saturation. The afterimage complementary of red is cyan, and when cyan is visually superimposed on blue-green, the patch will look "more" blue-green. Thus, the induced blue-green accentuates the focal blue-green present, which increases the amount of blue-green hue relative to the amount of white already present in the focal color (Agoston 201). Depending on the afterimage produced, for a different color patch, suppression may also be observed.

Simultaneous contrast occurring between same hues of different saturations is explained well by Agoston:

> Let us now consider what can occur if the color of the patch is at reduced purity, for example a red patch on a background that has the same hue but higher purity. The perceived saturation of the patch is diminished because the induced blue green suppresses some of the focal red. It is possible that, in a second patch of still lower purity, the blue green may be just sufficient to suppress the focal red and leave a neutral gray appearance. In the third patch of purity lower than that of the second, the induced blue green will be more than enough to suppress the focal red; the patch will have a faint blue green appearance. (201)

A gray patch placed against a lighter gray or white background appears darker than when it is placed against a darker gray or black background. This well known experience can also be explained by simultaneous contrast. Thus, achromatic patches appear lighter and their saturation lower if they are placed against a background that is darker.

The effects of simultaneous contrast are not restricted only to the perception of a patch on a relatively larger background. The perceived color of the background is also effected by the color of the foreground patch according to the same rule.

The third possible psychological effect related with contrast is the edge contrast. The effect caused by simultaneous contrast on a focal area appears uniform. If two areas of uniform colors having the same hue but slightly different luminance factor are viewed, adjacent to the boundary between the two areas, there is a relative enhancement of lightness of the lighter area and a corresponding darkening of the adjoining darker area (Agoston 206). If a black line is drawn along the edge at which two areas join, the effect of edge contrast is lost. The edge contrast phenomenon is caused psychophysically by interactions among nerve cells in the retina. It is also referred to as the Mach-band effect, the Mach contrast (named after the physicist Ernst Mach), or the border contrast. Agoston explains the psychophysical reactions that cause the edge contrast as follows:

> [. . .] a peak of perceived lightness is explained by unequal influences from the left and right areas. When the eye is focused on the lighter side of an edge, the response is suppressed less by the darker area on one side than by the lighter area on the other side. Hence the relatively high net response is made evident locally by the perceived increase of lightness. The opposite effect, a dip of lightness, is noted on the darker side where the net response is relatively low. There the response is suppressed more by the lighter area than by the darker area. (207-208)

The final possible effect that may be experienced during contrast perception is assimilation (reversed contrast). In pointillist paintings, dots of selected colors are

put on a surface to be perceived as a spatial mixture (optical mixture). The phenomenon of perceiving dabs of distinct colors as shifting towards each other is called assimilation. An example would be strips of colors, namely red, yellow, and blue. The red strips on the yellow background appear yellowish, and on the blue background, the same red strips appear bluish.

Assimilation is also known as the Bezold Spreading effect. Assimilation should not be confused with simultaneous contrast. In simultaneous contrast, a red area surrounded by a yellow area would tend to look more bluish (not yellowish); surrounded by a blue area it would tend to look more yellowish (not bluish) (Agoston 209). The nature of effect that will take place is related to the size of the images cast on the retina. Following Jameson and Hurvich, Agoston explains the phenomenon as follows:

> A receptive field is a retinal region served by one interconnecting nerve cell which responds to stimuli imagined anywhere within the region. Thus, if there are receptive fields that are sufficiently small compared with a retinal image, the resolution of the red strips (above) will be good and simultaneous contrast will be produced locally. If at the same time there are receptive fields that are so large that they cannot differentiate the detail of the strips, they will simply report an average response (for the red and yellow, or the red and blue). Thus the presence of large and small receptive fields would produce both the good resolution and average mixture observed. Assimilation involves the blending of hues and brightnesses, but with the maintenance of the perceived pattern. It is regarded as a kind of spatial averaging. (209)

Following the argument of Agoston, it is also valid to introduce a relation between the viewing distance and the effect that will be perceived. As the viewing distance

is increased, producing retinal images of finer detail would be more possible, and a transition from simultaneous contrast to assimilation will occur. Finally when a distance is reached beyond which the pattern is distinguishable, the visual experience of pointillism takes over.

2.4.3 TYPES OF CONTRAST

2.4.3.1 LUMINANCE CONTRAST (BRIGHTNESS CONTRAST)

The eye is more sensitive to luminance contrast than to chromatic contrast. The urge to define luminance contrast by a mathematical formula, lead scientists first to measure the minimum perceptible change at each level of brightness, and then to compare it with the brightness at that level. Here brightness was defined as the perceived luminance. The minimum perceptible contrast was first defined with the equation:

$$C_{min.} = \Delta B / B$$

This equation was modified by omitting the subscript "minimum" and accepting contrast as C, unrestricted contrast. The numerator (ΔB), which had been the smallest incremental increase (or decrease) that could be detected, has become the difference between two luminances without limit. Luminance instead of brightness was used in the modified formula, due to luminance being a relatively more measurable variable. The denominator (B), which had been the adapting brightness, was altered to be one of the luminances found in the numerator, not necessarily the

adapting luminance. That is how specialists in the field defined the suprathreshold contrast (Erhardt 21).

Erhardt continues his argument on suprathreshold contrast by first explaining, and then criticizing the well and widely accepted *1981 IES Lighting Handbook*:

> The 1981 *Handbook* gives three variations of the equation that differ in the value given the denominator:
>
> $$C = (Lg - Ll) / (Lg), (Ll), \text{ or } (Lg + Ll)$$
>
> Lg is the greater luminance
>
> Ll is the lesser luminance
>
> Examine three arrangements of a white of 80 percent reflectance, and a black of 10 percent reflectance, illuminated to 100 fc. The three equations yield contrast values of 0.875, 7.0, and 0.778 respectively. The first is the contrast of a white field with a black target; in the second, the contrast is reversed but its parts carry the same reflectance; the third is a split field, half white and half black. (21)

In the *1984 IES Lighting Handbook Reference Volume*, Kaufman provides the same definition and formulas for luminance contrast, thus Erhardt's argument still holds on. Erhardt carries his argument one step further by comparing the formula with Munsell reflectance for its values:

> Consider two contrasts arising from the Munsell value scale: the first, between values 1 and 2, the second between 8 and 9, both illuminated uniformly to 100 fc. Using the second *Handbook* equation, the first contrast is 1.50, the second, 0.38. Since the Munsell steps represent equal perceptual contrasts, it is evident that the new equation does not provide answers that correspond to our experience. We must, therefore, conclude that the equation has no reasonable counterpart in the real world. (21)

As demonstrated above, contrast should not be interpreted as subtraction, but rather as a ratio. One of the earliest studies on chromatic luminance contrast was conducted by Kelly, who selected 22 colors of maximum contrast to use in color-coding (see table 2.3) (Agoston 92-93).[5]

Table 2.3

Kelly's List of Colors of Maximum Contrast

Color selection number	ISCC-NBS color name	ISCC-NBS centroid number	Luminance factor *Y*	Munsell value V
1	White	263	0.90	9.5
2	Black	267	0.0094	0.8
3	Vivid yellow	82	0.59	8.0
4	Strong purple	218	0.14	4.3
5	Vivid orange	48	0.36	6.5
6	Very light blue	180	0.57	7.9
7	Vivid red	11	0.11	3.9
8	Grayish yellow	90	0.46	7.2
9	Medium gray	265	0.24	5.4
10	Vivid green	139	0.19	4.9
11	Strong purplish pink	247	0.40	6.8
12	Strong blue	178	0.13	4.1
13	Strong yellowish pink	26	0.43	7.0
14	Strong violet	207	0.10	3.7
15	Vivid orange yellow	66	0.48	7.3
16	Strong purplish red	255	0.15	4.4
17	Vivid greenish yellow	97	0.63	8.2
18	Strong reddish brown	40	0.070	3.1
19	Vivid yellow green	115	0.40	6.8
20	Deep yellowish brown	75	0.070	3.1
21	Vivid reddish orange	34	0.24	5.4
22	Dark olive green	126	0.036	2.2

Source: Agoston 92.

[5] See K. L. Kelly, "Twenty-two Colors of Maximum Contrast," *Color Eng.* 3.6 (1976): 26-27, qtd. in Agoston 92-93.

Each color in Kelly's table contrasts maximally in lightness (luminance contrast) with the one immediately preceding it in the list, and also contrasts, with the earlier ones. The first nine colors provide maximum contrast not only for persons with normal color vision, but also for those with color-deficient vision or color blindness (red-green deficiency). Agoston comments on Kelly's findings that if, in the list, the pairs of colors are not additive complementaries, then they are exhibiting predominantly lightness contrasts (Agoston 92-94).

Kelly's criterion was that the farther apart two points were in the CIE color space, the more discriminable they were. Carter and Carter also have supported this criterion. They found out that a difference of about 40 CIELUV units or less is too small to be generally useful in high-contrast applications. It should be noted that when two chromaticity points get more distant from each other in the two-dimensional CIE (x , y) diagram, approaching the boundaries, the more saturated both points become. The author believes it should be explained more in terms of color attributes causing contrast, thus defining high luminance contrast colors and high chromatic (saturation) contrast colors separately.

2.4.3.2 COLOR CONTRAST (CHROMATIC CONTRAST)

A visual task may have an inherent contrast when uniformly illuminated. This type of contrast is caused by the chromatic information, the attribute of "saturation," of the colors on that task (Kaufman 3-15). This is called color contrast. Kelly, and Carter and Carter worked on identifying high contrast colors, and their criterion

was that two chromatic points on a CIE Color Space would have higher contrasts if they were further apart in this space. In the 3D Color Space the same pair of hues can be distanced both with their luminance values, *Y*, and with their saturations. Kelly, and Carter and Carter seem to pick pairs that justify both conditions on the optimum. If the luminance contrasts of the high-contrast color pairs are set aside, only the saturation variable is left. When colors of about equal lightness (luminance), that are complementary or near complementary, of moderate or high purity (saturation) are situated immediately adjacent to one another, they produce an uncomfortable sensation called vibration. Some color pairs of high-contrast are likely to produce this sensation, which may be the reason Kelly, and Carter and Carter preferred to use a three dimensional space and all the three attributes of color, instead of limiting it to two variables. The information on the attribute of "saturation" in providing contrast is limited and not enough to derive any conclusions.

3 COLOR AND ATTENTION

3.1 EXPERIMENTAL RESEARCH ON THE EFFECT OF COLOR ON ATTENTION: COLOR IN ISOLATION

In most of the studies that have treated color in isolation, red was suspected to be the hue attracting the most attention, and this section presents some of the scholarly studies on the red phenomenon. These studies may be classified under two headings: studies that suspected red had an arousal property inherent in itself, and studies that argued red carried unique signal properties.

Humphrey noted that red was the most common color signal in nature. He explained this with red contrasting well both with green foliage and the blue sky. Red being the color of blood, it was thought to be able to trigger instincts of animals. What red signaled was pretty ambiguous. It might signal either approach (sexual display, edible food, etc.) or avoidance (aggressive behavior, poisonous substance, etc.). Humphrey thought one's response to red was a reflexive one. It made viewers prepare themselves to take some form of action that was defined by the context.

Kaiser argued that it was unlikely to give a direct physiological response to color, but rather one might make certain associations to colors and that these might in turn mediate a physiological response (Clearwater 25).[6] One explanation related to the exceptional dominance of red in attracting attention comes from the operational mechanism of the eye. The lens of the eye has to adjust to focus the red light wavelengths, as their natural focal point lies behind the retina. Thus, red advances, creating the illusion that red objects are closer than they actually are (Mahnke and Mahnke 11). Red may or may not have a signaling property that effects either the consciousness or the subconsciousness of the viewer. Experimental research carried out on colors' arousal properties does not supply enough data to derive a conclusion from their findings. On the other hand, experiments on colors' advancing property are found to be very useful and explanatory for attention studies on color.

Luckiesh provided one of the earliest arguments on the "retiring" and "advancing" effects of color letters placed in the same plane (Clearwater 66).[7] In 1918, he used an apparatus with red and blue filters ("of fairly high purity") with which he altered the color of the letters "X" and "E" viewed inside wooden boxes. The subjects moved the red "X" until it appeared to lie in the same plane as the blue "E." He found a lot of intersubject variability, but still in most of the cases it was necessary

[6] See P. K. Kaiser, "Physiological Response to Color: A Critical Review," *Color Research and Application* 9.1 (1984): 29-36, qtd. in Clearwater 25.

[7] See M. Luckiesh, "On "Retiring" and "Advancing" Colors," *Amer. Jour. of Psychology* 29 (1918): 182-86, qtd. in Clearwater 66.

to move the red "X" further away in order to make it appear to be in the same plane with the blue "E."

Successive studies on the advancing property of color found instances when blue was judged to be "nearer" than red. Pillsbury and Schaefer, in 1937, had subjects view either red neon or blue neon and argon lights (Clearwater 66-67).[8] When the lights were placed equidistantly, the blue light was judged the nearer. The explanation for this "conflict" in apparent nearness of red vs. blue is explained by subsequent research that suggests brightness to be the controlling quantity for apparent distance (Taylor and Sumner, Johns and Sumner). The Purkinje shift, a well-known physiological phenomenon, demonstrates that blue light appears brighter than red at low luminance levels. Thus, it is to be expected that the subjects of Pillsbury and Schaefer judge blue light as more advancing ("nearer") than the red light at low luminance levels if brightness is the main criterion in judging "nearness."

These studies of isolated colors focused on the process that triggered human faculties for attention. Psychological or physiological arousal or illusive apparent "nearness" might attract attention, although the reasons were not explicitly stated or discussed. The studies suggest brightness to employ the greatest role in attracting attention. Studies on color combinations, which will be in the following

[8] See W. B. Pillsbury and B. R. Schaefer, "A Note on Advancing-Retreating Colors," *Amer. Jour. of Psychology* 49 (1937): 126-30, qtd. in Clearwater 66-67.

section, seem to strengthen this view. On the other hand, the dominance of red in the visual field has not lost validity, especially in high brightness conditions. In order to expand on this issue, experiments with color combinations and foreground-background relations will be examined next.

3.2 EXPERIMENTAL RESEARCH ON THE EFFECT OF COLOR ON ATTENTION: COLOR COMBINATIONS

Mount, Case, Sanderson, and Brenner conducted the first outdoor research of color distance in 1956 (Clearwater 69-71).[9] They mounted four colored (yellow, green, red, blue) and four gray papers on plywood. The plywood with colors and grays attached on it was viewed outdoors against a dirt bank under full sun. Subjects compared a color or a gray against a dark or light gray standard on each trial. Subjects were asked to match each color in brightness with one of the standard grays. Additionally, subjects were asked to view the plywood through shutters designed to restrict field of vision to papers, bank, and sky. This time they were asked to judge which of the two papers visible through the shutters appeared closer. It was found that each color was judged to be closer than its nearest matching gray. Each of the hues and the grays appeared closer when viewed against a dark standard rather than the light one. They found no difference in "advancement" for one hue over another. On the other hand, as saturation of a color was increased with respect to its background, its apparent position advanced

[9] See G. E. Mount, H. W. Case, J. W. Sanderson, and R. Brenner, "Distance Judgment of Colored Objects," *Jour. of Gen. Psychology* 55 (1956): 207-214, qtd. in Clearwater 69-71.

(an effect equal at most to 1.5% of the standard distance). Colors having high brightness contrast with their background appeared advancing (an effect equal at most to 3% of the standard distance). Thus, their research findings suggest that increasing relative contrast by increasing an object's brightness and/or saturation as compared to its background makes the object appear closer.

These findings are supported by the 1960 study of Oyama and Nanri (Clearwater 71).[10] They had subjects compare standard and variable circular shapes in all combinations of achromatic and chromatic relations on varying backgrounds under laboratory conditions. They found that the apparent size of the figure increased as its brightness increased, while the brightness of the background decreased. They found no effect of hue on apparent size.

Egusa confirmed the findings of the studies above (Clearwater 71-72).[11] In 1983 he found an effect of hue when hemifields of different hues were compared for perceived depth. The green-blue difference in perceived depth was smaller than the red-green difference, with red appearing nearer. He also noted that a higher saturated color was judged nearer when it was red or green, but there was no such effect for the blue.

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[10] See T. Oyama and R. Nanri, "The Effects of Hue and Brightness on the Size Perception," *Japanese Psychological Research* 2.1 (1960): 13-20, qtd. in Clearwater 71.

[11] See H. Egusa, "Effects of Brightness, Hue and Saturation on Perceived Depth Between Adjacent Regions in the Visual Field," *Perception* 12.2 (1983): 167-75, qtd. in Clearwater 71-72.

In the studies above, it appears that there may be a combined effect of all attributes of color, hue, saturation, and brightness, on attention. The effectiveness of the attributes depends on the context of presentation. Brightness seems to be the most dominant attribute. Colors having high brightness contrast with their backgrounds appear advancing. Saturation seems to be the second most important attribute of color in judgments of "nearness." As saturation of a color increases with respect to its background it seems closer in the visual field.

3.3 OTHER STUDIES ON COLOR AND ATTENTION: CONTRAST

From the experimental work presented and discussed above, brightness contrast and color contrast appear to effect human attention. There have been many studies not only to define contrast, but also to determine colors or brightness levels of maximum contrast. These studies have been presented and discussed in section 2.4 under the topic "Contrast." In these studies, some scholars sought large color differences to make objects as conspicuous as possible, as in safety signs, signals, commercial packaging, advertising, etc. These studies tried to define and determine colors of high contrast. They presume that highly contrasting colors have better signaling properties when used together. The term "signaling" is usually used to attract attention to something, but the nature of attracting attention may differ in various applications. If there is text involved in the intention of "signaling," as in safety signs, advertisements, etc., then the problem of legibility comes together with attracting attention. If there are borders or definite shapes involved, then the problem of visibility comes into consideration. Most of the studies concentrating

on colors of high contrast take into consideration legibility and/or visibility in their studies for attracting human attention. Kelly, and Carter and Carter, two of the best known studies in the area, have been discussed in section 2.4.3.

One of the purposes of studying contrasting colors has been to aid the establishment of standards. These standards may associate colors with levels of hazards or may establish warning messages to attract attention of the users in communicating hazards associated with a product. In the 1999 study of Leonard, it was emphasized that most studies in this field were not empirical. Leonard studied the effect of color on warnings of risk. It was found that the background color produced a significant difference only when the signal words lacked salience in the presented format. It was concluded that the shape or other graphical configurations might serve better than color to convey levels of risk. In this study, color combinations for signaling suggested by various standards organizations were not found to fit the population's stereotypes. On the other hand, red was found to be associated with risks at all levels.

Studies on colors of high contrast seek mainly to find colors that are geometrically or numerically distanced to each other on a maximum level in a color system (see sec. 2.4.3). The studies involve calculable definitions and explanations for contrasting colors. The calculated maximum contrast may not necessarily be an indication of the best possibility in attracting attention.

3.4 SUMMATIVE IMPLICATIONS ON COLOR AND ATTENTION FROM PREVIOUS STUDIES

Summative implications on color and attention from the above findings suggest that:

1. Colors apparently advancing in the visual field may have a potential for attracting attention.
2. Red appears to be advancing in the visual field. It also attracts attention in more instances compared to other hues.
3. Attention cannot be solely attributed to hue alone.
4. Attention is influenced most by contrast effects: saturation and/or brightness differences between objects and their backgrounds.
5. Colors having high brightness contrast with their background attract more attention.
6. As saturation of a foreground color increases with respect to its background color, it attracts more attention.

4 COLOR AND PREFERENCE

4.1 EXPERIMENTAL RESEARCH ON COLOR PREFERENCE: COLOR IN ISOLATION

Early investigations on color preference focused on the process employed to arrive at a preference judgment, not on preference judgments ascribed to colors.[12] Many of the associations made between a color and particular preference ratings were of an emotional nature. The main question of these early studies remained: Are certain colors able to consistently elicit certain emotions? Some of these studies measured preference in terms of one evaluative dimension: pleasantness/unpleasantness. A high pleasantness rating for a given color, thus, became synonymous with a high preference rating. After the semantic differential was introduced in 1957 by Osgood, Suci, and Tannenbaum, preference research shifted from single relationship of color-pleasantness towards ratings on a series of bipolar adjective scales (semantic differentials). This shift resulted in color profiles which could be attributed to a specific color or which underlie a group of colors.

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[12] Some of these works are cited and discussed by Clearwater (28-29). See R. D. Norman and W. A. Scott, "Color and Affect: A Review and Semantic Evaluation," *Jour. of General Psychology* 46 (1952): 185-223, T. Nakashima, "Contributions to the Study of the Affective Processes," *Amer. Jour. of Psychology* 20 (1909): 157-93, and M. F. Washburn and S. L. Grose, "Voluntary Control of Likes and Dislikes: The Effect of an Attempt Voluntarily to Change the Affective Value of Colors," *Amer. Jour. of Psychology* 32 (1921): 284-89.

Moreover, a new research interest developed that investigated the hypothetical relationship between colors and various mood tones. Most of these early studies lacked control over three psychological dimensions of color: hue, saturation, and brightness. In addition, their research findings were not statistically analyzed and illumination was not adequately controlled. These studies focused almost solely on the dimension of hue.

Guilford was one of the pioneers in attempting to study the individual contributions of hue, saturation, and brightness on affective responses to color (Clearwater 29-30).[13] In 1934, Guilford selected 40 colors: 18 hues that are equal in saturation and brightness, 11 hues varying in brightness and low in saturation, and 11 hues in high saturation. Each color was judged on a nine-point pleasantness scale, from greatest possible unpleasantness (1) to greatest possible pleasantness (9). He found that with saturation and brightness held constant, the hues blue, green, red were rated more preferred, and yellow, orange less preferred. Colors having high brightness were found to be preferred over low brightness ones, and saturated colors over unsaturated ones. He also observed difference in the choices of male and female subjects.

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[13] See J. P. Guilford, "The Affective Value of Color as a Function of Hue, Tint and Chroma," *Jour. of Experimental Psychology* 17 (1934): 342-70, qtd. in Clearwater: 29-30.

Smets examined contributions of brightness and saturation to pleasantness ratings in 1982 (Clearwater 30).[14] Smets sampled 24 colors and subjects rated colors on pleasant/unpleasant basis. She found contributions of the two attributes of color to ratings with saturation accounting for 88% of the variance and brightness for 12%.

Eysenck opened an argument on color preferences by suggesting a universal scale of preference (Clearwater 31-32).[15] He calculated the average ranks for six saturated colors at differing brightnesses, which he derived from previous studies in the literature. He recorded responses of 21,060 subjects. He reported preferences for saturated colors from most to least preferred being blue, red, green, violet, orange, and yellow. He compared his findings with previous studies and concluded that there was no racial difference in color preferences and no differences regarding gender. For Eysenck, preferences for any color varied inversely with the luminosity factor (brightness) of that color, and liking a given color had a direct relationship with its differentiation from white. Eysenck only included saturated colors in his research and did not specify extensively the experimental conditions of the studies he compared his study with.

Granger constructed sets of stimuli from Munsell colors where one color attribute (hue, saturation or brightness) would vary while the other two were held constant

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[14] See G. Smets, "A Tool for Measuring Relative Effects of Hue, Brightness and Saturation in Color Pleasantness," *Perceptual and Motor Skills* (1982): 1159-64, qtd. in Clearwater: 30.

[15] See H. J. Eysenck, "A Critical and Experimental Study of Color Preferences," *Amer. Jour. of Psychology* 54 (1941): 385-91, qtd. in Clearwater 31-32.

(Clearwater 32).[16] He concluded that, given isolated colors, the order of preference for all three attributes remained invariant from level to level throughout the color space. He found hue to be the major factor in determining preference. In his study, 5B (blue) was most preferred, and 5Y (yellow) was least preferred. He observed that background contributed to preference choices. According to Granger, preference for a color increased the more it contrasted in its hue (color contrast) with the background against which it was seen. He also noted that as saturation increased, a color was preferred more up to a certain point. Colors seen as too vivid were rated as less preferred. Granger concluded also that color preferences were only in part determined by objective stimulus qualities.

Guilford and Smith examined the roles of hue, saturation, and brightness (value) on preference ratings with a ten-point pleasantness scale that was used to rate 316 stimulus papers, 295 of them from Munsell colored chips. Independent from varying levels of brightness, female subjects preferred blue-green regions the most, and yellow, yellow-green regions the least. Although this pattern existed across all levels of brightness, as brightness increased perceived pleasantness also increased. Moreover, they found that within a given hue, the greater the saturation, the greater its perceived pleasantness was. Guilford and Smith cautioned their readers by emphasizing that color combinations, color as applied to objects, and the interaction of color and texture was not included in their study. This made the study difficult to apply in real life situations.

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[16] See G. W. Granger, "An Experimental Study of Color Preferences," *Jour. of General Psychology* 52 (1955): 3-20, qtd. in Clearwater 32.

Sivik, in 1974 and 1975, investigated 71 colors representing the NCS color space on 26 semantic differential scales answered by a stratified sample of Swedish adults (Clearwater 42-43).[17] His factors involved excitement, evaluation, potency, and temperature. He found that as the degree of blackness increased (low brightness), colors were less preferred. This consistent finding across all hues, varied for the degree of dislike within the hue. For example, a much darker blue is found to be at the same degree of judged dislike with a moderate dark yellow. He also found that there were more instances of blue being preferred despite its change in brightness or saturation. This observation supports the account for blue often being cited as the most preferred color.

In a more recent study, dating 1999, Saito investigated color preferences in Japan among 586 university undergraduates (Blue and 7*)*. When this subject group, of mean age of 20.4 years old, was asked to name their preferred color, most of them chose blue (37.1%), followed by red (11.1%). He found an effect of gender on preferences: black being chosen more by men and pink being selected more by women. It should be noted that the study asked to name the preferred color, but did not involve a visual stimulus for it. An earlier study of Saito, in 1996, compared color preferences in Japan, China, and Indonesia. He asked 490 subjects (175 Japanese, 158 Chinese, and 157 Indonesian) to choose, this time from a color

[17] See L. Sivik, "Color Meaning and Perceptual Color Dimensions: A Study of Color Samples," *Goteborg Psychological Reports* 4.1 (1974), and L. Sivik, "Studies of Color Meaning," *Man-Environment Systems* 5 (1975): 155-160, qtd. in Clearwater 42-43.

chart, the three colors they liked most and the three they liked the least (A Comp.-Study of Col. Pref.). He found statistically that each country significantly differed from each other in the selection of colors of certain hues, but that a high preference for white was common to all.

Wijk, Berg, Sivik, and Steen studied preferences of 80-year-old men and women in 1999. The preference order for seven colors was found to be blue, green, red as most preferred, and brown as the least. The preference order of colors for younger subject groups found by earlier studies may have a possibility to show some stability also in old age.

From the studies presented above on color preference in isolated colors, the somewhat consistent result is that, blue appears to be a preferred color, while yellow is not. In all of the cases excluding Eysenck, brightness seems to have a direct relationship with pleasantness. As brightness of a color increases, its' preference rating also increases. The effect of saturation seems similar to the effect of brightness. The rating of a color increases when its' saturation increases. In all of these studies color was being dealt with in isolation. It was not applied to a context. Colors, in almost all cases, were judged against a neutral background, gray or black.

4.2 EXPERIMENTAL RESEARCH ON COLOR PREFERENCE: COLOR COMBINATIONS

Washburn and Grose, in 1921, observed that making their subjects imagining a given color in combination with another color changed their affective ratings for that color (Clearwater 34-35).[18] The first systematic attempt to study color combination effects came from Helson and Lansford in 1970.

Helson and Lansford presented 125 color chips against 25 colored backgrounds under five different illumination sources to 10 subjects. Although their study is among one of the best-controlled experimental setups, the small number of subjects is often being cited as a concern. Color chips were selected from each main region of the Munsell hue dimension combined with low-medium-high examples of brightness (value) and saturation (chroma). Subjects were shown twelve color chips on a background and made absolute judgments on a nine-point scale. Their data showed that pleasantness ratings were a product of an interaction between light source, background color, and object color. Background color was found to be the single most important component of pleasantness judgments due to contrast effects. They found that background colors of either high or low brightness (value) and very low saturation (chroma) enhanced judged pleasantness of object colors. Brightness (value) was the most important factor for pleasant color harmony: the greater the brightness contrast, the more likely one is to have a color combination

[18] See M. F. Washburn and S. L. Grose, "Voluntary Control of Likes and Dislikes: The Effects of an Attempt Voluntarily to Change the Affective Value of Colors," *Amer. Jour. of Psychology* 32 (1921): 284-89, qtd. in Clearwater 34-35.

perceived as good. Independent from background color and light source, blue B, purple-blue PB, green G, blue-green BG were judged most pleasant. Yellow and purple ranked low.

Reddy and Bennett, in 1985, researched color combinations in a cross-cultural study (Clearwater 36).[19] They found brightness contrast between background and object color to be the major factor in pleasantness ratings. The three cultural groups varied slightly only in the hues they disliked. This study implied a similar pleasantness rating for all of the three cultural groups involved.

In all of the above studies, contrast seems to play an important role in preference relations. The studies demonstrate that the perceived pleasantness of a color is changeable and is not an invariant quality of the color itself. The studies state that brightness contrast is directly related with preference in the sense that as the brightness contrast between background and the stimulus color is increased, the color's preference rating also increases. These experiments also demonstrate that color combinations can be experimentally investigated and their results can serve as a tool, despite being crude and limited, by which one may begin to make color decisions in the built environment.

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[19] See T. V. Reddy and C. A. Bennett, "Cultural Differences in Color Preferences," *Proc. of the Human Factors Society, 29th Annual Meeting, 1985*: 590-93, qtd. in Clearwater 36.

Color preferences may be effected by many variables from the context the colors are viewed to individual differences among the subjects. Viewing context, namely environmental factors may be well controlled in laboratory settings.

In all of the above studies, color preferences are being regarded as constant over time. The Walters, Apter, and Svebak study of 1982 showed that color choices varied with time (Clearwater 37).[20] They asked office workers to select the color they preferred every 15 minutes over the course of 5 to 40 hours. Individuals did not prefer one color across all trials. Changing individual preferences in every 15 minutes revealed by this experimentation does not tell much. The question of whether the consensus of the choices remained the same over this 15 minutes time span was left unanswered in that study.

In this dissertation, preferences of individuals showed consistency over time (2-4 weeks time span). The supplementary image sets were presented to the same subject group, starting 2 weeks after the main image set was shown, for over a period of 2 weeks. The time span between viewing of the main image set and the supplementary image sets was varying between 2 to 4 weeks depending on the subjects as they were instructed to participate in the test "whenever they felt like it." The supplementary image sets only contained four background colors: red, yellow, cyan, and blue. For the red and cyan backgrounds the subjects significantly singled out the same hues with the ones they preferred for the main image set,

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[20] See J. Walters, M. J. Apter, and S. Svebak, "Color Preference, Arousal, and Theory of Psychological Reversals," *Motivation and Emotion* 6.3 (1982): 193-215, qtd. in Clearwater 37.

despite the time span. There was no consensus on any preferred hue on the yellow and blue backgrounds in the main image set. As time passed, and subjects were exposed to the yellow background for many times, they arrived at a consensus.

The one important issue here is that color combinations have not been studied as widely and intensively as colors in isolation. In the available studies, the concentration was on the color preference rating, and how background altered that rating. None of the studies intended to examine the most preferred color combinations giving equal weight to the background color and the stimulus color. This issue was taken into consideration more by researchers in the art field under the topic "color harmony."

4.3 OTHER STUDIES ON COLOR PREFERENCES: COLOR HARMONY

The art world has treated color in a different manner. They extensively studied color, especially color combinations, and tried to define their own experiences and "taste" of color. These studies are designated as *expert views* in this dissertation. Sometimes, they have also conducted qualitative research based on interviews or observations, but have not made use of controlled environment setups. Lacking quantitative data does not necessarily mean that research on color harmony is not valuable. Some of the studies that are going to be reviewed here are helpful to explain many visual phenomena on color. Unfortunately, they cannot be relied on a broader scientific context to generalize human response to color. On the other hand, it should not be underestimated as many shaped the way color was applied in

art and design, the emergence of different styles in art, and the creation of myths on color.

During the Renaissance period, Leonardo da Vinci, in his *A Treatise on Painting*, reflected his personal taste as: "Of different colors equally perfect, that will appear most excellent is seen near its direct contrary: a pale color against red; a black upon white [. . .] blue near yellow; green near red: because each color is more distinctly seen, when opposed to its contrary, than to any other similar to it" (qtd. in Birren 55).[21]

In the eighteenth century, Sir Isaac Newton suggested that harmony of colors was related to their "vibrations" (wavelengths):

> May not the harmony and discord of Colours arise from the proportions of the Vibrations propagated through the Fibres of the optick Nerves into the Brain, as the harmony and discord of Sounds arise from the proportions of the Vibrations of the Air? For some Colours, if they be view'd together, are agreeable to one another, as those of Gold and Indigo, and others disagree. (346)

Color circles are established to study the relationship of colors with each other and to understand harmony of colors. They generally present color samples in the sequence of spectral hues, as found in a rainbow. A color circle is completed by inserting the nonspectral hues (purples and purplish reds) between violet and red.

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[21] See Leonardo da Vinci, *A Treatise on Painting* (London: George Bell and Sons, 1877), no page numbers are indicated, qtd. in Birren 55.

Colors selected to form a color circle are arranged in a geometrical manner, such that pairs of complementary colors (additive complementary pairs) or afterimage complementary pairs are directly opposite to each other (Agoston 45).

Goethe introduced a six-member color circle consisting of three afterimage complementary hue pairs, represented in opposing geometrical locations (Agoston 45) (see fig. 4.1).

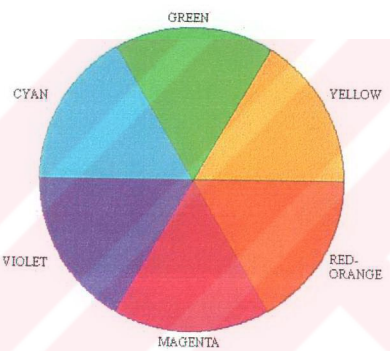

Fig. 4.1 Goethe's Color Circle (Agoston 45).

It was not until the nineteenth century that more explanatory studies on color harmony were undertaken. One of the earliest studies on color harmony or "good" color combinations dates back to 1854 with most famous and admired color expert of the time: M. E. Chevreul. Chevreul set forth definite principles of color harmony, which have been included in teachings of basic color education for years

ever since. Chevreul differentiated color harmony into two: harmony of analogous colors and harmony of contrasting/complementary colors.

In the color circle that Chevreul used, red, yellow, and blue were stated as primaries, where orange, green, violet were secondaries, and red-orange, yellow-orange, red-violet, etc. were intermediate hues (see fig. 4.2). Harmony of analogous colors was the colors that lie next to each other on this color circle. For example, red with red-orange, orange, red-violet, or violet would be a harmonious analogous color combination. Harmonies of direct opposites or complements would be colors facing each other on the color circle. For example, red with green, yellow with violet, orange with blue, etc. Harmonies of split-complement would be a color with the two colors that lie on the sides of its direct complement. Examples

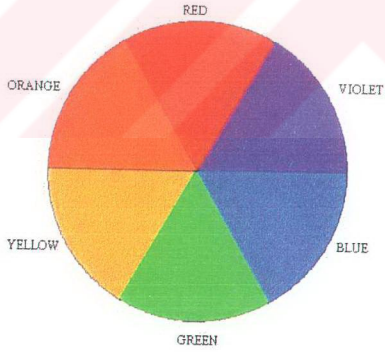

Fig. 4.2 Chevreul's Color Circle.

would be red with yellow-green and blue-green, blue with red-orange and yellow-orange, etc. The list of Chevreul extends to harmonies of triads (combinations with three colors), harmonies of tetrads (combinations with four colors), etc. Chevreul became famous for his Law of Simultaneous Contrast. Being a chemist and working with dyes, he was well-aware of scientific methods of his time and indicated that: " [. . .] I do not pretend to establish rules based upon scientific principles, but to enounce general propositions, which express my own peculiar ideas" (Chevreul 81). Despite the lack of scientific data, he had full confidence in his principles of harmony that he wrote: "I hope that many classes of artists, particularly dressmakers, decorators of all kinds, designers of patterns for textiles fabrics, paper-hangings, &c., will derive some benefit from consulting them" (Chevreul 179).

Albert H. Munsell, the inventor of the most widely used system of color notation, also worked on color harmony. His principles were based on personal taste. Munsell was known to have a conservative taste of late Victorians (Birren 63). Some of Munsell's principles on color harmony are (Birren 63-64):

1. Brightness (value) used in combined colors should always have the middle (5) of 9 gray steps as a balancing point. A combination of 1,5,9 (black, medium gray, white) or 3,5,7 or 4,5,6 provides harmonious combinations of value according to Munsell.
2. Monochromatic harmonies should be solved with the above principle. For example, a color of medium 5 value and medium 5 chroma can be combined

with a 3 or 7 or 4 or 6 value of the same hue. It can also be combined with 3 or 7 or 2 or 8 chromas of the same hue.

3. Complementary colors are considered to be harmonious, but within certain rules. A red of 5 value can be combined with blue-green of 5 value. Or a chroma 5 red can be combined with a chroma 5 blue-green, and so on.
4. Neighboring hues can be combined with split-complements but should be balanced according to 5.
5. Munsell stated his formula for color harmony as: "Beauty could be proved if all areas were measured and put on a disk, and if the spun result was a neutral value-5 gray, all would be well!" (qtd. in Birren 64).

Itten introduced a twelve-part color circle to build his theories on color harmony (*Design and Form* 32-33). His color circle begins with the three primary colors: yellow, blue, and red. The secondary colors are orange, violet, and green. He arranged his color circle so that two diametrically opposed colors were complementary (see fig. 4.3). Itten referred complementary colors as harmonious pairs: red/green, blue/orange, yellow/violet were such harmonious pairs. The only requirement of Itten to obtain harmonious pairs was that the two colors be symmetrical with respect to the center of the sphere (*The Elements of Col.* 72).

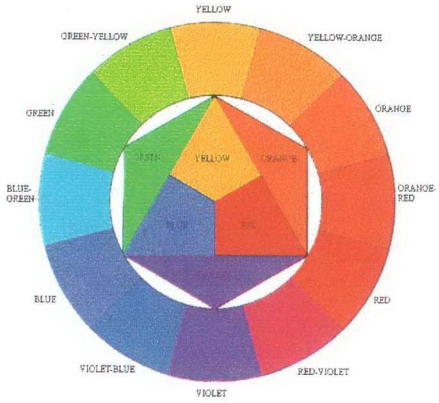

Fig. 4.3 Itten's Color Circle (*The Elements of Col.* 31).

Artists, designers, and art historians have been studying the effects of colors for centuries and have developed a multitude of theories on the harmony of colors. The number and variety of these theories imply that their dealing with color depends much on their individual experiences. The color circles developed in order to study color harmony are most of the time geometrical arrangements, which is a reflection of their individual experiences.

4.4 SUMMATIVE IMPLICATIONS ON COLOR PREFERENCES FROM PREVIOUS STUDIES

Regardless the apparent value of the above studies on color preference, whether in isolation, in combination, or from an expert view, caution should be taken in interpreting them. The experimental setups and the findings from which researchers

of the above studies derived their conclusions should be considered carefully.

Summative implications on color preferences from the above findings suggest that:

1. Color preferences and decisions are not simply questions of personal taste. There is some consensus on color preferences.
2. Data on the effects of biological factors, culture, gender, fashion trends, age, and time is not enough to generalize into a conclusive statement.
3. Blue appears to be a preferred color, while yellow is not.
4. Brightness seems to have a direct relationship with pleasantness of colors in isolation.
5. Saturation seems to have a direct relationship with pleasantness of colors in isolation.
6. Brightness contrast seems to have an effect on perceived pleasantness of foreground-background color relationships.
7. Color contrast may have an effect on color preferences on colored backgrounds, but the subject has not been extensively studied.
8. Color combinations or color harmony has not been studied scientifically enough to formulate favorable color choices on specific backgrounds.

5 EXPERIMENTAL RESEARCH ON FOREGROUND-BACKGROUND COLOR RELATIONSHIPS

5.1 RESEARCH HYPOTHESES

The main concern of this dissertation is to study foreground-background color relationships in terms of attention and preference. An experiment was designed for this purpose. The experiment was centered around color squares and the background color that those squares were viewed on by subjects. Responses for attention and for preference were collected separately. For both attention and preference, answers for the following hypotheses were investigated to reveal foreground-background color relationships:

1. Hue has an effect on the choices on a specific background color.
2. Varying brightness-saturation levels of color samples have an effect on the choices on a specific background color.
3. The hue of a background has an effect on the choices of color samples.
4. The location of a color sample on the computer screen has an effect on the choices.
5. Gender of the subjects has an effect on the choices.

5.2 THE EXPERIMENT

The experimental setup consisted of a computer monitor located in a windowless room, illuminated with cove lighting. Figures 5.1 and 5.2 show photos of the setup. Cove lighting was preferred as it excluded the possibility of glare on the monitor and created a perfect diffuse environment without any highlights that might have distracted the subjects. Standard Philips TL 54 fluorescent, having 6200 color temperature (CT) and 72 color rendering index (CRI) was used for lighting in the room.

The experiment verbally asked the subjects two questions:

1. Which color square attracts your attention the most on the background color on the screen? (Ekranda gördüğünüz fon üzerinde hangi renk karesi en çok dikkatinizi çekiyor?)
2. Which color square would you prefer on the background color on the screen? (Ekranda gördüğünüz bu fonda en tercih ettiğiniz renk karesi hangisidir?)

The two questions of the study were stated before the test. No time limits were set for making the decisions. The researcher waited until subjects decided on a particular color square, and then proceeded on to the next image. Subjects were tested individually for the main image set over a period of 5 to 10 minutes, depending on their response speed. They were asked to view the monitor through a headrest (see fig. 5.1). The eye-movement recording equipment was attached to that headrest. The headrest also assured a fixed viewing angle covering the

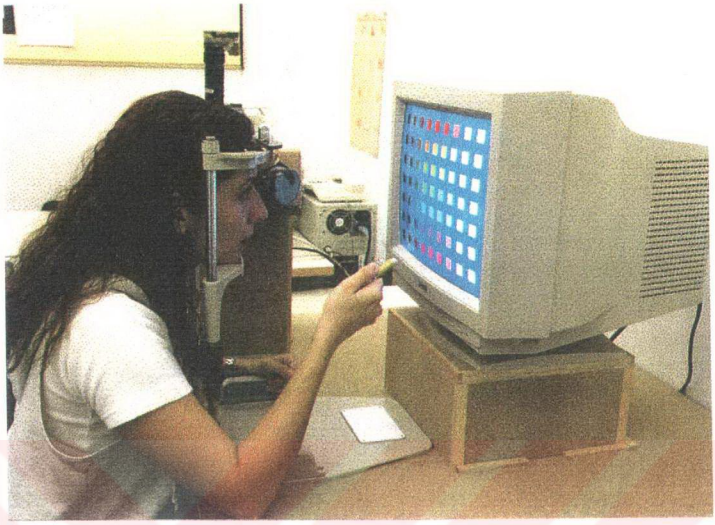

Fig. 5.1 Experimental Setup, where Subjects View the Image Sets through a Headrest.

Fig. 5.2 Environment of the Experiment.

computer monitor, and a fixed viewing distance for each subject. The viewing distance was 25 cm from the monitor. Subjects were then asked to show their choices with a laser pointer. The researcher recorded each shown choice. For the supplementary sets, subjects sat around the computer monitor, having a viewing distance of about 100-120 cm. They were each given a data sheet on which they wrote down their choices (see app. C). Each supplementary test was answered over a period of 10 to 20 minutes, depending on the individual response speed. The supplementary tests took more time to answer due to the increased number of images to be viewed.

Images were shown through a computer monitor. Each image consisted of a colored background and 63 color squares of differing hues, saturations, and brightnesses (see app. B). The preparation of the images is explained in section 5.4 (see table 5.2). Each subject viewed and answered the experiment questions for eight background colors. These eight background colors were shown successively, starting with 0^0 (red) on the HSB color circle (see fig. 5.7), continuing with 45^0 distances, ending at 315^0 (magenta). When an image was initially shown, the subjects were asked to wait for a few seconds for visual adaptation, before answering the questions. Despite the quantity of color squares to choose from (63 color squares for each background), the subjects had no difficulty in choosing one over the others. Making a single choice took about 10-15 seconds for one subject, although varied from an approximate of 5 seconds to 50 seconds due to individual response speed. No matter how long it took to choose a single color square, none of the subjects showed any difficulty or hesitation in making a selection of a single color square. The exceptions to this

were squares with brightness of 0% (namely black), and squares with saturation of 0% (namely white). The white and black squares were included in the images within the same grid pattern. Thus, there was a column of 7 white squares and a column of 7 black squares, which were and appeared the same. Subjects were made aware of the situation, so they just picked one among the 7 if they made a black or a white choice. In the statistical analysis, these 7 whites and 7 blacks were each treated as the same, reducing the choices into white and black.

Besides the main image set, three more image sets were shown to subjects who answered the same questions for those as well. These supplementary sets were investigating the effect of location of the color squares on the choices

The experiment questions on attention and preference were asked to the subjects verbally. In order to understand the relation between how their eyes moved and the responses they have given, eye-movements were recorded. The color square that attracts the most attention is where the eyes are expected to move towards and stay for a while. In other words, the eye-movement is expected to fixate on a particular color square more than any other (see sec. 1.1). Similarly, for making a preference, eye-movements are expected to fixate on two or more color squares, and then make saccadic movements between those squares in order to make a choice.

Eye-movements were recorded with a video camera that had necessary attachments devised to obtain a clear image of the eye (see fig. 5.3). The time (in minutes and seconds) was recorded for each viewing. Thus, a record of the time

spent for each image was obtained. The continuous recordings of the eye-movements were analyzed relative to the image shown at the time. For every subject, the eye-movement recordings were analyzed, and it was recorded every time the eye of the subject fixated for at least one second (see table 5.1). The overall pattern of viewing was also followed by observing the general behavior of the eye.

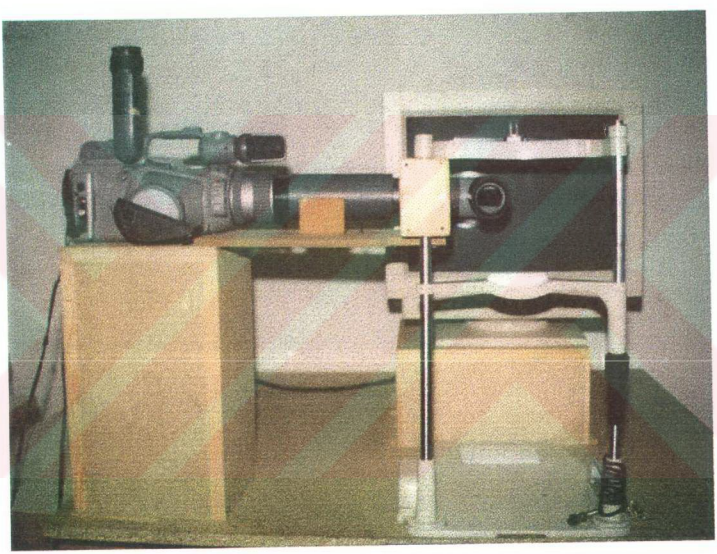

Fig. 5.3 Devised Eye-movement Recording Equipment.

The devised equipment did not allow detection of fixations of less than one second. Each eye-movement recording lasting more than one second was captured as an image. The captured image was transferred to *Jasc Paint Shop Pro* software. For each captured image, the mid-point of the pupil was determined on the image

Table 5.1

Eye-movement Record Sheet for Subject No. 1

Subject: 1 Tape No: 1

Notes: An overall scanning of the image. Looked at everywhere on the image with very brief saccades. Blinked her eyes a lot. Moved her eyes everywhere on the image.
bgr. = background

	Image	Counter	Duration	Location
1		00:02	-	(97, 97)
2		00:04	-	(137, 97)
3		00:06	-	(163, 97)
4		00:08	-	(193, 96)
5	calibration	00:10	-	(233, 95)
6		00:12	-	(160, 49)
7		00:14	-	(156, 92)
8		00:15	-	(162, 96)
9		00:17	-	(173, 109)
10		00:20	-	(183, 129)
11	red bgr./attention	00:33-00:37	4 sec.	(162, 97)
12		00:41-00:44	3 sec.	(157, 97)
13	red bgr./preference	00:44-00:46	2 sec.	(160, 96)
14		01:06-01:09	3 sec.	(174, 129)
15		01:12-01:14	2 sec.	(173, 116)
16	yellow bgr./attention	01:14-01:16	2 sec.	(165, 91)
17		01:25-01:28	3 sec.	(148, 91)
18	yellow bgr./preference	01:41-01:43	2 sec.	(129, 94)
19		01:47-01:49	2 sec.	(186, 115)
20		01:52-01:57	5 sec.	(179, 114)
21	yellow-green bgr./attention	02:09-02:12	3 sec.	(153, 98)
22	yellow-green bgr./preference	02:23-02:28	5 sec.	(184, 115)
23	green bgr./attention	02:43-02:49	6 sec.	(147, 99)
24	green bgr./preference	03:01-03:03	2 sec.	(171, 117)
25	blue bgr./preference	04:06-04:13	7 sec.	(156, 97)
26	purple bgr./attention	04:17-04:20	3 sec.	(158, 94)
27	purple bgr./preference	04:46-04:50	4 sec.	(144, 104)
28	magenta bgr./preference	05:08-05:10	2 sec.	(168, 90)

with the paintbrush function (see fig. 5.4). This function enabled to record the coordinates of the pupil on the image. These coordinates were written down under the title "location" in the eye-movement record sheet (see table 5.1). The coordinates found were then plotted on a blank file that was the same size (pixel wise) with the captured recording. A copy of the blank file with fixation plots was then juxtaposed on the image shown to the subject at that particular recording. To achieve this, first the shown image was resized to have the same size with the blank file (pixel wise), and then the blank image was pasted onto the shown image with edit/paste/transparent selection function.

At the very beginning of each eye-movement recording, subjects were asked to fixate their eyes on points on a black and blank image with the instructed order (see fig. 5.5) This process was called calibration. In this way, the maximum coverage area of the eye was determined for each subject. The four outer points of the image corresponded to the very edge lines of the computer monitor. Thus, the four framing points of the monitor (and the images shown) were determined. The four corners of the calibration image were taken as reference points. When the four framing points obtained from the calibration were juxtaposed with their places on the images shown, the places of the fixations were determined.

An example of the process is provided in figure 5.4. Subject 1 made only three fixations for the yellow background for preference (see table 5.1). The final choice of the subject on yellow background for preference was purple-saturation 75 (S75). This choice is the third fixation that the subject made during her examination of the image.

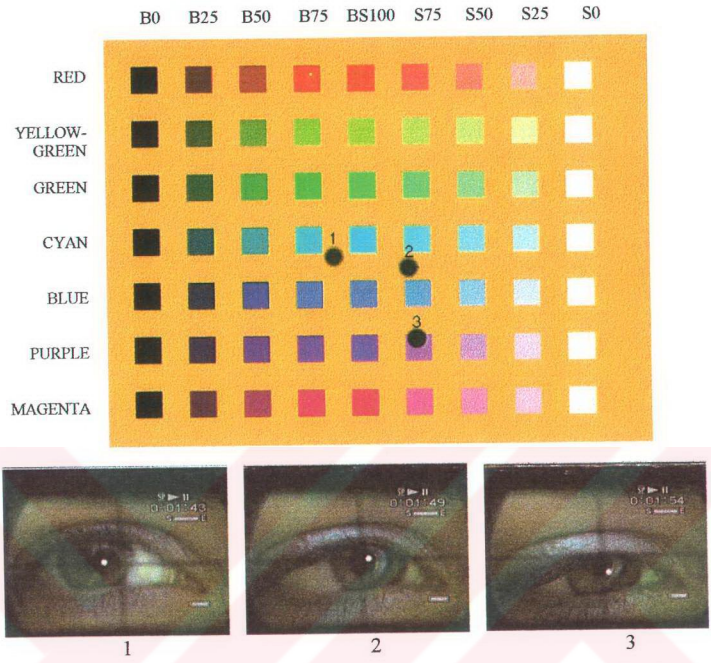

Fig. 5.4 Eye-movement Analysis for Subject No. 1 during the Viewing of Yellow Background for Preference.

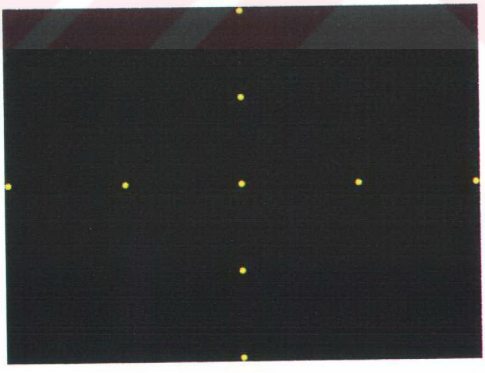

Fig. 5.5 Image Shown on the Computer Monitor for Calibration.

T.C. YÜKSEKÖĞRETİM KURULU
DOKÜMANTASYON MERKEZİ

In general, responses of the subjects corresponded with their eye fixations. Moreover, the eye-movement patterns were similar, consisting of a general scanning of the image for a few seconds, and then fixating on two, or at the most, three color squares. Some subjects found the square they were asked to immediately after the quick scan, and did not even spend time on a second alternative. The analysis of the eye-movements of the subjects revealed no inconsistency between viewing pattern and the responses given. Thus, the eye-movement recordings did not provide any additional information. For this reason, eye-movement recordings and their analyses are not included in this dissertation.

The researcher conducted the experiment herself, collecting the responses for the main image set (responses for the supplementary sets were written down on the data sheets by the subjects themselves), and observing the subjects throughout the whole experiment. The subjects were instructed that this was not a test to evaluate their personal abilities, and that their choices were totally subjective and personal. However, it was also stated that their personal data was important for the research to evaluate the sample group in general.

A total of 123 subjects took part in the experiment. 121 of them partook in the main image set. 108, 100, and 48 of the subjects participated in the three supplementary image sets respectively. All the subjects were students at Bilkent University, Faculty of Art, Design, and Architecture, located in Ankara, Turkey. Subjects were asked to fill in a brief questionnaire about themselves (see app. C), where they were asked of their age, gender, department of study, grade,

educational background, vision problems/deficiencies, education on color, and interest in color.

The majority of the subjects were between 20-24 in age (78%), second year students (55%) in the Department of Interior Architecture and Environmental Design (81%). 41% of the subjects were male, while 59% of them were female (see app. D).

All of the subjects were from urban areas. There were no subjects from small towns or rural areas. The majority of the subjects were from Ankara (76%), followed by İzmir (7%) and İstanbul (5%). Detailed information on cities that subjects came from can be found in appendix D.

93% of the subjects had courses related to color in their education. 7% of the subjects stated that they have not have any color education at all. They all had an interest in color with the exception of 6% who stated that they were not interested in the subject at all. Most of the subjects had a general interest in color (68%), while some have extended their interest into color related hobbies (26%).
A detailed description of the subject group is included in appendix D.

Before the test, subjects were asked if they had any eye or vision deficiencies. Subjects with vision deficiencies were asked to take the test with their correction equipments, namely contact lenses or eyeglasses, which they wore regularly. There were no subjects with severe eye or vision damage who needed to be

excluded from the test. Subjects were also given *Ishihara's Tests for Colour-Blindness* (Ishihara).

Ishihara's Tests for Colour-Blindness is a series of plates designed to provide a test that gives a quick assessment of color vision deficiency. It determines the commonest form of color vision disturbances; the most commonly seen among them being red-green deficiency. The test controls whether the subject has a red-green deficiency, which may be of two types: a protan (which may be complete (protanopia), or partial (protanomalia)) and a deutan (which may be complete (deuteranopia) or partial (deuteranomalia)).

Subjects viewed Ishihara's Tests in the very same room with the experimental setup, under the same lighting conditions. Anybody unable to read any of the plates shown was not used as a subject.

5.3 EQUIPMENT

Computer monitor: All images were viewed through a 17" computer monitor using *ACDSee '95* software (see fig. 5.2).

Video camera: A Sony-Video Hi8 CCD-VX1E Handycam Pro was used with the necessary attachments devised to record eye-movements (see fig. 5.3).

Headrest: A typical headrest used by medical doctors for eye examinations was used to assure a fixed viewing angle and a fixed viewing distance (see fig. 5.1).

Laser pointer: To ensure that they did not move their heads, subjects were provided with a small laser pointer to indicate their choices (see fig. 5.1).

Ishihara's Tests for Colour-Blindness: Subjects were tested with plates to detect any color vision deficiencies.

Questionnaire: A questionnaire was given at the end of the test in which age, gender, department of study, academic grade, cities lived in, visual deficiencies, education related to color, and individual interests on color were asked. A copy of the questionnaire is given in appendix C.

5.4 THE IMAGE SETS

Adobe Photoshop 4.0 software was used to create the entire image sets. The screen area was adjusted to 1024X768 pixels for every image produced. All images were created in JPEG format and RGB mode. The Adobe Photoshop Color Picker function was used to create displayed colors (see fig. 5.6). Foreground and background colors were selected from a color spectrum based on the HSB color model. The Adobe Photoshop Color Picker displays color values using a number of different color models (RGB, HSB, CMYK, and Lab). Once the user enters numerical values of color attributes for one of the color models, by using the software, it is possible to convert these values automatically for rest of the color models (see fig. 5.6).

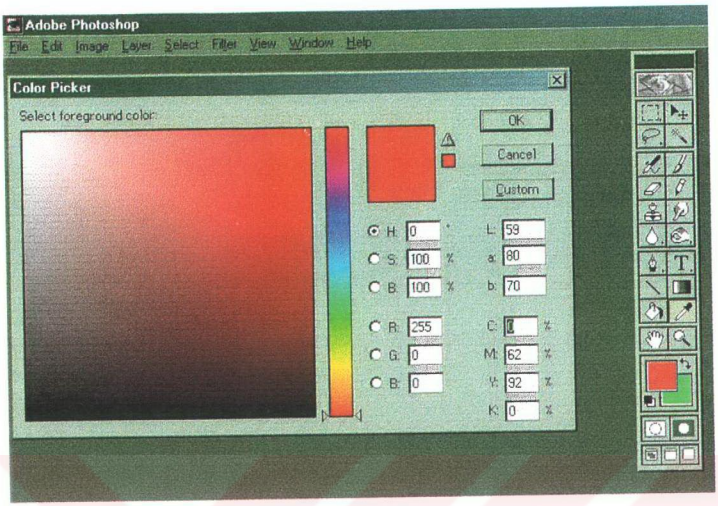

Fig. 5.6 Adobe Photoshop Color Picker Function.

HSB lets the user choose a color with a hue from 0^0 to 360^0, and with saturation and brightness values from 0% to 100%. The angle for hue is defined as an angle relative to pure red on the color circle. In the HSB model, all colors are described in terms of three fundamental characteristics: Hue, Saturation, and Brightness (HSB) (see fig. 5.7).

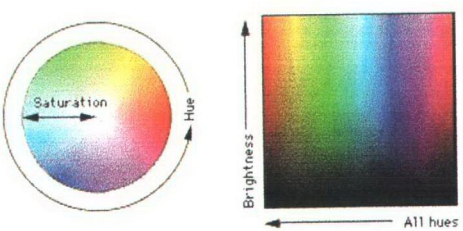

Fig 5.7 The HSB Model of Adobe Photoshop.

Adobe Photoshop 4.0 User Guide defines these characteristics as follows:

> Hue is the wavelength of light reflected from or transmitted through an object. More commonly, hue is identified by the name of the color such as red, orange, or green. Hue is measured as a location on the standard color wheel (color circle) and is expressed as a degree between 0^0 and 360^0.
>
> Saturation, sometimes called chroma, is the strength or purity of the color. Saturation represents the amount of gray in proportion to the hue and is measured as a percentage from 0% (gray) to 100% (fully saturated). On the standard color wheel, saturation increases as one approach the edge of the wheel; saturation decreases as one approach the center.
>
> Brightness is the relative lightness or darkness of the color and is usually measured as a percentage from 0% (black) to 100% (white). (65)

5.4.1 THE MAIN IMAGE SET

The main image set consisted of 8 images representing 8 backgrounds. The HSB model was used from the Adobe Photoshop Color Picker function. The model was derived from the HSB color space (see sec. 2.3). Information on the algorithm of color generating function of the software was not available. Thus, the adjustments made on the HSB color space to make it usable with the software could not be obtained. The HSB model of the software was chosen to generate all the colors on the monitor. All of the background colors had 100% saturation and 100% brightness. Thus, they were fully saturated and bright. Hues were selected from the standard color circle starting with red 0^0, continuing with 45^0 intervals, ending at magenta 315^0. A list of background colors is as follows:

0^0 Red, 100% saturation, 100% brightness

45^0 Yellow, 100% saturation, 100% brightness

90^0 Yellow-green, 100% saturation, 100% brightness

135^0 Green, 100% saturation, 100% brightness

180^0 Cyan, 100% saturation, 100% brightness

225^0 Blue, 100% saturation, 100% brightness

270^0 Purple, 100% saturation, 100% brightness

315^0 Magenta, 100% saturation, 100% brightness

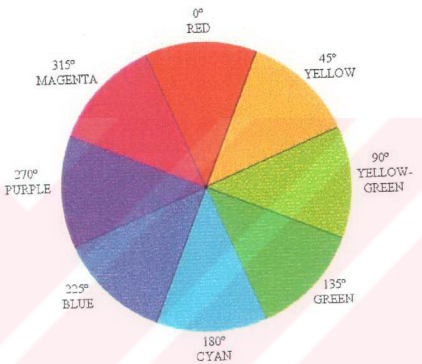

Fig. 5.8 Color Circle Used in this Dissertation.

On every background color, all the remaining hues (excluding the background hue itself) were represented in 7 separate rows. Each hue row was then divided into 9 columns, where the hue was represented with varying brightness and saturation levels. The basic scheme is presented in table 5.2. The images are included in appendix B.

Table 5.2

Placement Scheme of Color Squares on Backgrounds

HUE 8/ BACKGROUND

	B0% S100%	B25% S100%	B50% S100%	B75% S100%	B100% S100%	B100% S75%	B100% S50%	B100% S25%	B100% S0%
Hue 1									
Hue 2									
Hue 3									
Hue 4									
Hue 5									
Hue 6									
Hue 7									

B: Brightness
S: Saturation

5.4.2 SUPPLEMENTARY IMAGE SETS

Three different supplementary image sets were prepared to test the location effect. The researcher investigated whether any particular brightness-saturation range (column) or hue range (row) were preferred independent of their place in an image. The first two image sets were scrolling sets. One of them was where the rows were scrolling downwards, and the other was where the columns were scrolling to the right. The last supplementary set was a rotating set, where the

whole image was rotated clock-wise with 90^0 intervals (0^0, 90^0, 180^0, 270^0). All the supplementary sets were applied on four backgrounds, which were paired as angular opposites of each other on the HSB color circle. The backgrounds used for the supplementary sets were: red 0^0 - cyan 180^0 and yellow 45^0 - blue 225^0. All the images for the supplementary sets are included in appendix B.

6 DATA ANALYSIS

Analysis of Variance (ANOVA), the statistical method for comparing several means, was applied to the collected data. ANOVA tests the null hypothesis (H_0) that the population means are all equal. The alternative hypothesis (H_a) is that they are not all equal. The null hypothesis is rejected when at least one of the means of several groups differ from the rest. The data analysis was designed as randomized complete blocks. The data was arranged into homogeneous groups and was compared for a number of treatments. For the main image set the homogeneous groups (blocks) were different amounts of brightness-saturation levels as presented in columns to the observer, while the treatments were differing hues as presented in rows to the observer. The randomized block designs assume that "if each treatment is applied to exactly one unit in the block and comparisons are only drawn between treatment responses from the same block, extraneous variability should be greatly reduced" (Johnson and Bhattacharyya 592). The purpose of reducing the error variance in this statistical method is to increase the sensitivity of the test for detecting differences in the treatment means (Walpole, Myers, and Myers 495). The data structure of a randomized block design with b blocks and k treatments is represented in figure 6.1.

	Block 1	Block 2	...	Block *b*
Treatment 1	y_{11}	y_{12}	...	y_{1b}
Treatment 2	y_{21}	y_{22}	...	y_{2b}
.	.	.	...	.
Treatment *k*	y_{k1}	y_{k2}	...	y_{kb}

Fig. 6.1 Data Structure of a Randomized Block Design (Johnson and Bhattacharyya 593).

The data from the experimental research was structured in a similar manner. Tables concerning the data structures are included in appendix E. These tables are also generated to display the distribution of responses collected for each viewed image.

The SAS (Statistical Analysis System) software was used in the analysis of the collected data. The procedure was individually applied to the variables, attention and preference. Each background color was analyzed in terms of column-row effect using ANOVA procedure; where columns represent the effect of brightness-saturation and rows represent the effect of hue. The column effect tests the null hypothesis (H_0) that means of the choices for all brightness-saturation levels are all equal. The alternative hypothesis (H_a) is that they are not all equal (see sec. 5.1). The row effect tests the null hypothesis (H_0) that means of the choices for all hues are equal. The alternative hypothesis (H_a) is that they are not all equal (see sec. 5.1). Detailed information on class, levels, and values are listed in appendix F. Duncan's Multiple Range Test was also applied for variables,

attention and preference. Pairwise comparison for each possible pair is made by this test that provides information on differences between means of each individual class, brightness-saturation and hue, in the case of individual background colors. Results from the ANOVA Procedure and Duncan's Multiple Range Test are included in appendix G for each image shown.

Background effect was also investigated by making a data structure. The number of responses was tabulated for each hue and for each brightness-saturation range on every single background color represented in two different data tables. The background effect tests the null hypothesis (H_0) that means of the choices on all background colors are equal (see sec. 5.1). The alternative hypothesis (H_a) is that they are not all equal. Using ANOVA all these tables were analyzed.

Location effect was investigated by analyzing responses for each image that was viewed. In these images, the places of color squares were changing on the same background. The location effect tests the null hypothesis (H_0) that means of the choices for any place on the screen are all equal. The alternative hypothesis (H_a) is that they are not all equal (see sec. 5.1). Responses were statistically analyzed for each brightness-saturation and hue range for every image shown.

Gender effect was analyzed for the main image set by both tabulating the number of responses and applying ANOVA procedure. The gender effect tests the null hypothesis (H_0) that means of the choices for males and females are all equal. The alternative hypothesis (H_a) is that they are not all equal (see sec. 5.1).

Analyses of the responses to the experiment are presented in a descriptive manner, which are accompanied with tabulated count data and statistical results at the appendices (see apps. E, F, and G). Results from the Duncan's Multiple Range Test are also included in the appendices (see app. G). In the following section, data analysis are described as either statistically significant or not, depending on the p-value obtained from the ANOVA Procedure. The p-value of the ANOVA F-test is the probability that a random variable having the F-distribution is greater than or equal to the calculated value of the F-statistic. A small p-value indicates that the group means are different. If the p-value is small or smaller than preselected α (significance level), it can be said that the data are statistically significant at level α. The customary $\alpha = 0.05$ has been chosen, which means that it is required that the data give evidence against H_0 so strong that it would occur by chance no more than 5% of the time when H_0 is true. The term statistically significant is used to indicate that the evidence against the null hypothesis reached the standard set by $\alpha = 0.05$ (a p-value ≤ 0.05 is statistically significant).

6.1 ANALYSIS OF FOREGROUND-BACKGROUND COLOR RELATIONSHIPS FOR ATTENTION

Red Background

The test results show that brightness-saturation effect is statistically significant (p-value = 0.0001), although hue effect is not statistically significant (p-value = 0.2454) for the red background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 12.857, other means= 0.000–1.429). Thus, subjects have a tendency to select color

squares with BS100 when they are asked which color square attract their attention the most.

Referring to the tabulated response distributions at appendix E, a cyan color square (H180, S100, B100) seems to attract the most attention with 33 responses (27.27%). This color square is followed by a green color square (H135, S100, B100) with 24 responses (19.83%). It should be noted that cyan and green are adjacent colors on the HSB color circle.

Yellow Background

Statistical results obtained from the test show that brightness-saturation effect is statistically significant (p-value = 0.0001), but that hue effect is not statistically significant (p-value = 0.1821) for the yellow background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 12.000, other means= 0.143–1.571).

Referring to appendix E, a specific cyan color square (H180, S100, B100) seems to attract the attention most with 39 responses (32.23%).

Yellow-Green Background

The test results show that brightness-saturation effect is again statistically significant (p-value = 0.0001), while on the contrary hue effect is not statistically significant (p-value = 0.0780) for the yellow-green background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 11.000, other means= 0.143–1.714).

From appendix E, it can be seen that the central cyan color square (H180, S100, B100) seems to attract the most attention with 25 responses (20.66%). It is

followed by a magenta color square (H315, S100, B100) with 20 responses (16.53%), and a red color square (H0, S100, B100) with 19 responses (15.70%). It should be noted that magenta and red are adjacent colors on the HSB color circle.

Green Background

Statistical results obtained from the test show that brightness-saturation effect is statistically significant (p-value = 0.0001), but that hue effect is not statistically significant (p-value = 0.1210) for the green background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 11.000, other means= 0.000–2.000).

Referring to appendix E, the cyan color square (H180, S100, B100) seems to attract the most attention with 25 responses (20.66%). It is followed by a magenta color square (H315, S100, B100) with 19 responses (15.70%) and a red color square (H0, S100, B100) with 20 responses (16.53%). It should be noted that magenta and red are adjacent colors on the HSB color circle. These results are similar to the responses given to the previous yellow-green background.

Cyan Background

For the cyan background, the test results show that brightness-saturation effect is statistically significant (p-value = 0.0005), whereas hue effect is not statistically significant (p-value = 0.3443). The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 8.857, other means= 0.286–2.429).

This time, a magenta color square (H315, S100, B100) attracts the most attention with 28 responses (23.14%), which is followed by a red color square (H0, S100,

B100) with 13 responses (10.74%) (see app. E). It should be noted that magenta and red are adjacent colors on the HSB color circle.

Blue Background

The test results show that brightness-saturation effect is statistically significant (p-value = 0.0001), albeit hue effect is not statistically significant (p-value = 0.3382) for the blue background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 11.714, other means= 0.000–1.286).

Referring to tabulated response distributions at appendix E, the adjacent color squares of red (H0, S100, B100) and magenta (H315, S100, B100) seem to attract the attention most with a total of 44 responses (36.36%). On the other hand, yellow-green (H90, S100, B100) and green (H135, S100, B100) color squares seem to attract the attention to a considerable degree with a total of 29 responses (23.97%).

Purple Background

For the purple background, statistical results obtained from the test show that brightness-saturation effect is statistically significant (p-value = 0.0001), but that hue effect is not statistically significant (p-value = 0.2085). The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 12.143, other means= 0.143–1.429).

The adjacent color squares of red (H0, S100, B100) and magenta (H315, S100, B100) seem to attract the most attention with a total of 37 responses (30.58%). Two other competitives to red and magenta for the purple background are yellow-

green (H90, S100, B100) and green (H135, S100, B100) color squares that attract the attention to a considerable degree with a total of 36 responses (29.75%).

Magenta Background

The test results show that brightness-saturation effect is statistically significant (p-value = 0.0116), whereas hue effect is not statistically significant (p-value = 0.3343) for the magenta background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 12.429, other means= 0.000–1.286).

Referring to appendix E, the yellow-green and green color squares attract the most attention: yellow-green (H90, B100, S100) with 49 responses (40.50%), and green (H135, B100, S100) with 27 responses (22.31%).

6.2 BACKGROUND EFFECT ON ATTENTION

The test results show that brightness-saturation effect is statistically significant (p-value = 0.0001) on the choices for attention on any background color. The mean for BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 80.500, other means= 1.125–9.000). Thus, subjects have a tendency to select color squares with BS100 when they are asked which color square attract their attention the most, regardless which background color these squares are viewed on.

The hue effect is also statistically significant (p-value = 0.0002) on the choices for attention on any background color. Means obtained from Duncan's test show that

cyan (18.80%), magenta (15.29%), red (14.67%), yellow-green (13.33%), and green (12.91%) attract the most attention regardless of the background color. On the other hand, black (3.72%), purple (2.99%), and yellow (2.68%) attract attention the least.

6.3 LOCATION EFFECT ON ATTENTION

The researcher suspected that the location of color squares on the computer monitor might have an effect on the choices of the subjects for attention and preference. Three different image sets were prepared and presented to subjects to investigate the location effect. Each image set was then statistically analyzed. These supplementary image sets were made only for four background colors (red, yellow, cyan, and blue).

The first of the three supplementary image sets was where the rows scrolled down on the same background. In the images viewed, each row was assigned to a different hue. Thus, places of the hues were changing on the same background color. The hue effect was tested for this set, where a relation was sought for the hue choices on the background colors, regardless of the location of that hue on the image. The statistical test shows that the hue effect is statistically significant (p-value = 0.0001) for all of the four background colors viewed. For the red background, the means for yellow-green and cyan are statistically differentiated. For the yellow background, the means for cyan and red are statistically differentiated. For cyan and blue backgrounds the mean for red is statistically different from other means. Thus, yellow-green and cyan attract attention on red;

cyan and red attract attention on yellow; and red attracts attention on cyan and blue, regardless of their location on the monitor.

The second of the three supplementary image sets was where the columns scrolled to the right on the same background color. In the images viewed, each column was assigned to a different brightness-saturation level. Thus, places of brightness-saturation levels were changing on the same background. The brightness-saturation effect was tested for this set, where a relation was sought for the brightness-saturation choices on the background colors, regardless of their location on the image. The statistical test shows that brightness-saturation effect is statistically significant (p-value = 0.0001) for all of the four background colors viewed. For all of the four backgrounds (red, yellow, cyan, and blue) the mean for BS100 (Brightness=100, Saturation= 100) is statistically different from other means. Thus, the column containing the most saturated and brightest color squares attract the most attention on all of the four backgrounds, regardless of its location on the monitor.

The third and last of the supplementary image sets was where the image was rotated 90^0 clock-wise for four times. Both the location of rows (hues) and columns (brightness-saturation) changed due to this rotation. The same four backgrounds with the above image sets were viewed for this set as well. Statistically, the effects of brightness-saturation and hue were tested for this set. The test results show that brightness-saturation is statistically significant (p-value = 0.0001) for all of the four backgrounds. The mean for BS100 (Brightness = 100, Saturation= 100) is statistically different from other means, suggesting that color

squares of most saturated and brightest level attract the most attention. The hue effect tested for the third (rotating) image set is also statistically significant (p-value= 0.0001). For red and yellow backgrounds the mean for cyan is significantly different from other means, suggesting that cyan color squares attract the most attention, regardless of their location on the image. For the blue background, the mean for red is significantly different, indicating that red color squares attract the most attention.

It may thus be stated that the location of the color squares on the images shown does not have an effect on the choices of subjects for attention.

6.4 GENDER EFFECT ON ATTENTION

The gender effect was tested for each of the eight background colors for the main image set. The statistical tests show that there is no significant gender effect on the choices made for attention. P-values of the gender effect for the eight backgrounds are between 0.2473 and 0.5417.

6.5 ANALYSIS OF RESEARCH HYPOTHESES ON ATTENTION

1. Referring to the main image set, hue does not seem to have an effect on attracting attention on a specific background color (see secs. 5.1 and. 6.1). The supplementary image sets show that hue has an effect on attracting attention on a specific background color (see secs. 5.1 and 6.3). Thus, it is concluded that

the hue effect on attention is of secondary importance, and requires viewing of a specific background color more than once to come to a decision.

2. Varying brightness-saturation levels of color samples have an effect on attracting attention on a specific background color (see secs. 5.1 and 6.1).
3. Despite of the changing hues of the background, some brightness-saturation levels and some hues attract more attention (see secs. 5.1 and 6.2).
4. Despite of the changing locations of color samples on the computer screen, some brightness-saturation levels and some hues attract more attention (see secs. 5.1 and 6.3).
5. Gender of the subjects does not have an effect on the choices for attention (see secs. 5.1 and 6.4).

6.6 ANALYSIS OF FOREGROUND-BACKGROUND COLOR RELATIONSHIPS FOR PREFERENCE

Red Background

The test results show that both brightness-saturation effect (p-value = 0.0128) and hue effect (p-value = 0.0002) are statistically significant in preferences for the red background. The mean for blue is significantly different from other means (mean for blue (H225)= 4.6667, other means= 0.7778–2.2222). Thus, subjects have a tendency to prefer blue on red.

Yellow Background

For the yellow background, both brightness-saturation effect (p-value = 0.0003) and hue effect (p-value = 0.0209) are statistically significant. Personal preferences

on this background are very scattered. For this reason, no inference on specific hue and brightness-saturation choices is made for the yellow background.

Yellow-Green Background

The test results show that brightness-saturation effect is statistically significant (p-value = 0.0033), while on the contrary hue effect is not statistically significant (p-value = 0.9248) for the yellow-green background.

From appendix E, it can be observed that there was a tendency to prefer a red color square (H0, S100, B100) with 14 responses (11.57%). But, the statistical evidence is not strong enough to single out the red hue as a specific preference on yellow-green.

Green Background

Statistical results obtained from the test show that brightness-saturation effect is statistically significant (p-value = 0.0001), but that hue effect is not statistically significant (p-value = 0.1618) for the green background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 5.0000, other means= 0.5714–2.5714).

Referring to appendix E, a blue (H225, S100, B100) color square is preferred in 10 responses (8.26%), while magenta (H315, S100, B100) and red (H0, S100, B100) are preferred by a total of 13 responses (10.74%). It should be noted that magenta and red are adjacent colors on the HSB color circle.

Cyan Background

For the cyan background, the test results show that both brightness-saturation effect (p-value = 0.0084), and hue effect (p-value = 0.0001) are statistically significant. The mean for blue is significantly different from other means (mean for blue (H225)= 5.8889, other means= 0.7778–2.1111). It can be conveniently stated that blue is preferred on cyan background.

Brightness-saturation effect is also important for the cyan background. The three most preferred blue color squares on cyan background have the following brightness-saturation values (see app. E): (H225, S100, B100) with 12 responses (9.92%), (H225, S50, B100) with 11 responses (9.09%), and (H225, S25, B100) with 10 responses (8.26%).

Blue Background

The test results show that both brightness-saturation effect (p-value = 0.0001) and hue effect (p-value = 0.0064) are statistically significant for the blue background. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 5.7143, other means= 0.4286–2.7143).

Referring to tabulated response distributions in appendix E, a red color square (H0, S100, B100) is most preferred with 12 responses (9.92%).

Purple Background

For the purple background, statistical results obtained from the test show that both brightness-saturation effect (p-value = 0.0002) and hue effect (p-value = 0.0004) are statistically significant. The mean for magenta is significantly different from

other means (mean for magenta (H315)= 4.8889, other means= 0.1111–2.7778). In this test magenta is preferred on purple. The specific magenta of (H315, S50, B100) is the color square preferred the most with 14 responses (11.57%).

Magenta Background

The test results show that both brightness-saturation effect (p-value = 0.0200) and hue effect (p-value = 0.0001) are statistically significant for the magenta background. The mean for blue is significantly different from other means (mean for blue (H225)= 5.7778, other means= 0.5556–3.1111).

Referring to appendix E, the blue color square (H225, S100, B100) is preferred the most with 14 responses (11.57%), which is followed by two other zones of blue: H225, S100, B75 – H225, S100, B50, with a total of 15 responses (12.40%), and H225, S75, B100 – H225, S50, B100, with a total of 18 responses (14.88%).

6.7 BACKGROUND EFFECT ON PREFERENCE

The test results show that the brightness-saturation effect is statistically significant (p-value = 0.0001) on preferences. The mean for column BS100 (Brightness= 100, Saturation= 100) is significantly different from other means (mean for BS100= 30.250, other means= 3.500–17.625). Thus, subjects have a tendency to select color squares with BS100 when they are asked which color square they prefer on the backgrounds viewed. It should be noted that all the background colors shown also have 100% brightness and 100% saturation.

The hue effect is also statistically significant (p-value = 0.0001) on the choices for preference. Means obtained from Duncan's test show that blue is preferred the most, regardless of the background it is viewed on. The mean for blue is 34.429, while other means are between 3.500 and 20.286. From the tabulated response distributions it can also be observed that blue is preferred on any background color 241 times (24.90%).

6.8 LOCATION EFFECT ON PREFERENCE

The first of the three supplementary image sets was where the rows (hues) scrolled down on the same background. The hue effect was tested for this set, where a relation was sought for hue choices on the background colors, regardless of their location on the image. The statistical test shows that hue effect is statistically significant (p-value = 0.0001) for all of the four backgrounds viewed. For red, yellow, and cyan backgrounds the mean for blue is statistically different from other means. Thus, blue is preferred the most on these backgrounds, regardless of its location on the monitor. For the blue background, the mean for purple is statistically different, indicating a preference for purple on blue.

The second of the three supplementary image sets was where the columns (brightness-saturation levels) scrolled to the right on the same background. The statistical test shows that brightness-saturation effect is also statistically significant (p-value = 0.0001 for red, cyan, blue backgrounds; p-value = 0.0011 for the yellow background). For red and blue backgrounds the mean BS100 (Brightness=100, Saturation=100) is statistically different from other means.

Thus, the column containing the most saturated and brightest color squares is preferred on red and blue backgrounds, regardless of its location on the monitor.

The third and the last of the supplementary image sets was where the image was rotated 90^0 clock-wise for four times. The test results show that brightness-saturation is statistically significant (p-value = 0.0001 for yellow, cyan, blue backgrounds; p-value= 0.0005 for red background). For the red, yellow, and blue backgrounds the mean for BS100 (Brightness = 100, Saturation= 100) is statistically different from other means, suggesting that color squares with most saturation and brightness are preferred over the others. In the yellow background, BS100 is accompanied by B50 (Brightness= 50) and B75 (Brightness= 75) as the most preferred brightness-saturation levels, regardless of their location on the screen. For the cyan background, S25 (Saturation= 25) is the most preferred with a significantly different mean than the others. The hue effect tested for the third (rotating) image set is statistically significant as well (p-value= 0.0001 for yellow, cyan, and blue backgrounds; p-value = 0.0014 for red background). For red and cyan backgrounds the mean for blue is significantly different from other means, suggesting that blue color squares are preferred the most, regardless of their location on the image. For the yellow background, the mean for red is significantly different, indicating that red color squares are preferred on the yellow background.

6.9 GENDER EFFECT ON PREFERENCE

The statistical tests show that there is no significant gender effect on the choices made for preference. P-values of the gender effect for the eight backgrounds are between 0.0604 and 0.2215. The confidence level for all of the statistical analyses in this dissertation is accepted as 95% (p-value ≤ 0.05). Since the gender effect for some of the backgrounds had p-values around 0.06, tabulated response distributions were investigated. Red, yellow, green, and blue backgrounds were investigated due to their low p-values obtained on the gender effect (p-values between 0.0604 and 0.0686). None of the tabulations contain any information on strong differences between the choices of male and female subjects. It is concluded that there are no significant gender effect on preferences of the subject group.

6.10 ANALYSIS OF RESEARCH HYPOTHESES ON PREFERENCE

1. Hue has an effect on preferences on a specific background color (see secs. 5.1 and 6.6).
2. Varying brightness-saturation levels of color samples have an effect on preferences on a specific background color (see secs. 5.1 and 6.6).
3. Despite of the changing hues of the background, some brightness-saturation levels and some hues are preferred over others (see secs. 5.1 and 6.7).

4. Despite of the changing locations of color samples on the computer screen, some brightness-saturation levels and some hues are preferred over others (see secs. 5.1 and 6.8).
5. The gender of the subjects does not have an effect on the choices for preference (see secs. 5.1 and 6.9).

7 DISCUSSION OF THE FINDINGS

7.1 ATTENTION

The data gathered and analyzed in this dissertation show that brightness-saturation levels are more important in attracting attention, than specific hues viewed on varying background colors. In every background color, the BS100 range (Brightness = 100, Saturation = 100) was chosen as attracting the most attention (67%). This range contains color squares that are most saturated and brightest on the images shown. This finding, to some extent, supports previous studies of Taylor and Sumner, and Johns and Sumner, which stated brightness as the controlling factor for attracting attention (see sec. 3.1). These studies did not give much importance to saturation, which was found to be another determinant factor in this dissertation.

Egusa suggested that an increase in saturation would promote "nearness," and consequently attract attention (see sec. 3.2). This statement was verified by the findings of the experiment. The Mount et al. study emphasized the importance of brightness and/or saturation contrast on apparent advancement of a color (see sec. 3.2). The condition of this contrast relationship was set as increasing the brightness and/or saturation of the foreground object compared to its background. Due to the design of the experiment, the results of this dissertation do not provide

support for contrast relationships. All the background colors viewed were of maximum saturation and of maximum brightness. There was no option for the subject to choose a foreground color square which was "more saturated" and/or "brighter" than the background. Thus, the contrast relationship suggested by Mount et al. has not been tested within the scope of this study.

The subjects chose the BS100 range color squares on BS100 background colors. Thus, as the brightness and saturation levels of the background and the foreground were selected to be the same, hue choices (color contrast) gained importance as a determining factor in attention. In general, cyan (18.80%), magenta (15.29%), red (14.67%), yellow-green (13.33%), and green (12.91%) significantly attract attention on any background color (see fig. 7.1). Thus, the red, magenta range (30%) and the yellow-green, green, cyan range (45%) on the color circle attract the most attention. Luckiesh, Mahnke and Mahnke, and Egusa emphasized that red was apparently "nearer" or "advancing" in the visual field (see secs. 3.1 and 3.2). Data from the experiment demonstrated that red, magenta range competed with yellow-green, green, cyan range in attracting attention. There is no evidence in the present research that suggests red wavelengths to be more capable of attracting attention than other hues. Blue (9%), the non-colors of white (6%) and black (4%), yellow (3%), and purple (3%) attract attention the least on any background color viewed (see fig 7.1).

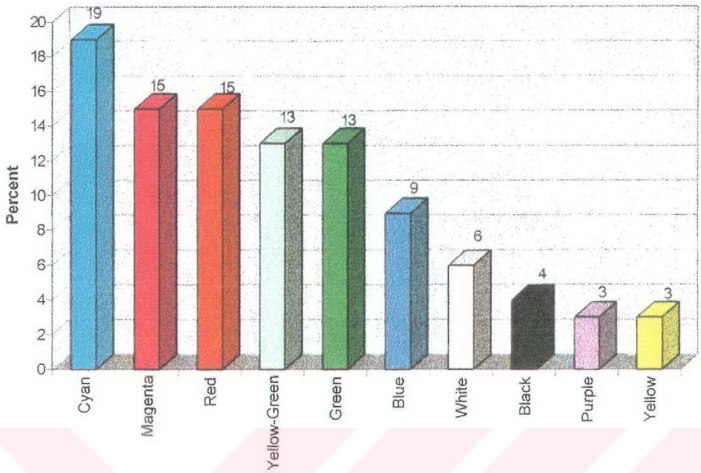

Fig. 7.1 Percent-scale of Attracting Attention for Hues on any Background Color.

Cyan attracts attention most on red (33%) and yellow (41%) backgrounds. Magenta and red attract attention on cyan (30% m., 17% r.). Red attracts attention on blue (35%).

No statistically significant hues stood out for the background colors of yellow-green, green, purple, and magenta in terms of attention. From the tabulated response distributions some inclinations for hues attracting attention on these background colors may be stated (see app. E). Magenta and cyan may attract attention on yellow-green (30% c., 29% m.), and green (28% m., 26% c.). Red, yellow-green, and green may attract attention on purple (26% r., 21% yg., 21% g.). Yellow-green and green may attract attention on magenta (46% yg., 29% g.) (see table 7.1).

Table 7.1

Hues that Attract Attention on Specified Backgrounds

Background Color	Stimulus Color
Red	Cyan (33%)
Yellow	Cyan (41%)
Yellow-Green*	Cyan (30%), Magenta (29%)
Green*	Magenta (28%), Cyan (26%)
Cyan	Magenta (30%), Red (17%)
Blue	Red (35%)
Purple*	Red (26%), Yellow-Green (21%), Green (21%)
Magenta*	Yellow-Green (46%), Green (29%)

* No statistically significant hues were differentiated for these background colors, thus inclinations from the tabulated response distributions have been included.

The statistical tests show that location and gender have no significant effect on the choices made for attention in this experiment.

7.2 PREFERENCE

The subjects were asked to single out the color square, which they thought suited best to the background color they viewed. The question was also stated as the most appealing color and the color they would prefer on the background color shown. The BS100 range is preferred the most by the subjects (25%). Therefore, color squares that are most saturated and brightest are preferred on backgrounds of most saturated and brightest colors. This finding supports experiments with isolated colors. Guilford, Smets, Guilford and Smith, and Sivik all stated that isolated colors of brighter and more saturated levels are more preferred (see sec.

4.1). Only Eysenck stated a contradicting result of brighter colors being less preferred (see sec. 4.1). The studies on color combinations, especially the ones with foreground-background color relationships suggested brightness contrast. Washburn and Grose, Reddy and Bennett demonstrated that in the judgments of subjects, as the brightness contrast increased, a more preferred color combination was obtained (see sec. 4.2). This argument cannot be evaluated within the scope of this study. There is no brightness contrast between the background and foreground colors in the preferences of subjects. It should be noted that the experiment in this study presented background colors as a condition. On the contrary, much of the literature on color combinations has investigated how various attributes of background colors enhance the pleasantness of foreground colors with varying background presentations. One exception to the preferred BS100 range is seen on the yellow background, where brightness levels of B50 (17%) and B75 (17%) are also preferred along with BS100 (23%). On the purple background, a saturation level of S50 (26%) is preferred along with BS100 (28%). Another exception is observed for the cyan background where saturation levels of S25 (24%) and S50 (14%) are also preferred along with BS100 (17%). In the third supplementary image set, a saturation of S25 is preferred over the other brightness-saturation levels for the cyan background (see table 7.2).

Table 7.2

Brightness–Saturation Levels that are Most Preferred on Specified Backgrounds

Background Color	Preferred Brightness – Saturation
Red	BS100 (21%)
Yellow	BS100 (23%), B75 (17%), B50 (17%)
Yellow-Green*	BS100 (26%)
Green	BS100 (29%)
Cyan	S25 (24%), BS100 (17%), S50 (14%)
Blue	BS100 (33%)
Purple	BS100 (28%), S50 (26%)
Magenta*	BS100 (22%)

See app. A for the abbreviations.

* The mean for BS100 was not singled out in the statistics, thus the tabulated response distributions were used.

Regardless of the background colors they viewed, the subjects preferred blue the most (25%) (see fig. 7.2). This corresponds with various findings of previous experimental research. Wijk et al., Guilford, Eysenck, Granger, Guilford and Smith, all found that blue was preferred the most when isolated colors were presented (see sec. 4.1). Sivik stated blue as the color preferred in more instances despite its change in brightness and saturation (see sec. 4.1). Saito stated blue as the color people named most when they were asked the color they liked best (see sec. 4.1). Washburn and Grose found that blue was the most preferred color regardless of its background (see sec. 4.2).

Data gathered in this inquiry demonstrated that green (8%), yellow (7%), yellow-green (6%) and non-colors of white (5%) and black (3%) were the hues that were preferred the least (see fig. 7.2). The studies of Guilford, Eysenck, Granger,

Guilford and Smith, and Washburn and Grose also stated yellow as the least preferred hue (see secs. 4.1 and 4.2).

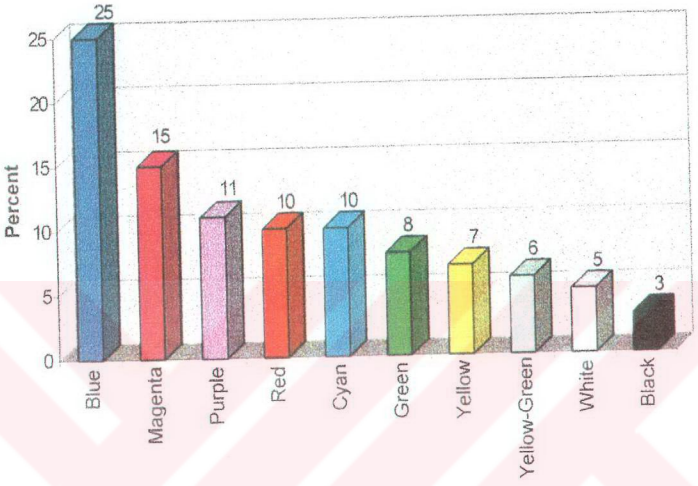

Fig. 7.2 Percent-scale of Preference for Hues on any Background Color.

Blue is preferred on the background colors of red (35%), cyan (44%), and magenta (43%). Magenta is preferred the most on the purple background (36%). Yellow and blue were background colors where it was hard to determine any agreement on preference. For the yellow background, the main image set showed a scattered distribution of preferences. The first supplementary set (scrolling down) statistically shows a preference for blue, while the last supplementary set (rotating) favored red as the preferred hue on a yellow background. The same subjects viewed all the image sets. Thus, it is concluded that yellow is a difficult background to make a hue preference, although there is a considerably significant

inclination towards preferring blue and/or red. A similar difficulty in deciding on preferences was found for the blue background. The main image set displays no single statistically significant preference on the blue background. Red (22%), purple (21%), magenta (20%), and cyan (15%) were preferred over other hues on this background. The first supplementary image set statistically singles out purple (20.5%) as the most preferred hue on blue background. The last supplementary set (rotating) shows red, magenta, and purple as preferred hues on blue. The yellow-green and green backgrounds have scattered response distributions. The subjects did not have a specific hue preference on the yellow-green and green backgrounds, but there seems to be an inclination towards preferring blue on these backgrounds (see table 7.3).

Table 7.3

Hues that are Most Preferred on Specified Backgrounds

Background Color	Preferred Color
Red	Blue (35%)
Yellow	Blue (23%), Red (17%)
YellowGreen*	Blue (19%)
Green*	Blue (21%)
Cyan	Blue (44%)
Blue	Purple (21%), Red (22%), Magenta (20%)
Purple	Magenta (36%)
Magenta	Blue (43%)

* No statistically significant hues were differentiated for these backgrounds, thus inclinations from tabulated response distributions have been included.

From the above list of foreground-background color relationships it can be concluded that blue was the most preferred color. Blue was preferred on every background color except on purple. The foreground-background color relationships presented above do not confirm the views of Granger, Chevreul, and Munsell concerning hue combinations (see secs. 4.1 and 4.3). There does not seem to be a harmony of either analogous or contrasting colors in making preference judgments . It may be interesting to research the issue further by excluding the dominant blue from the image sets. The exclusion of blue may direct subjects to suggest different color combinations, or may simply promote another dominant hue.

The statistical tests show that location and gender have no significant effect on the choices made for preference in this experiment.

7.3 DELIMITATIONS AND LIMITATIONS OF THE RESEARCH

The subjects for this study were students at Bilkent University, Faculty of Art, Design and Architecture, located in Ankara, Turkey. A majority of the subjects were Turkish students, between 20-24 in age, from Ankara, the capital city of Turkey. This demographic profile suggests a population of Turkish university students who have been living in a metropolitan environment for a considerable amount of time. This delimitation provides possibility to generalize the findings for the defined population. Comparisons with reviewed literature make it possible to place the findings in a broader frame. The results of this study, therefore, may not be directly applicable to individuals outside of the boundaries of the

population studied, except for the fact that it can be compared to and analyzed together with other research in the field. It may be interesting to apply the same experiment on subjects of varying social, cultural, and educational characteristics and compare the results with those presented in this dissertation.

The primary focus of this study was subjective responses of the subjects to the image sets. As such, it is not concerned with the correlates in the domains of psychophysics and physics. The study uses knowledge from the realm of psychology regarding personal judgment and subjective response. It is not concerned with emotions, thus leaves out the problems related to mood, etc. The experiments did not intend to attain any mood variations through color stimuli. On the other hand, in order to reduce the potential influence of mood, the subjects were told about the scope of the experiment beforehand, and were asked to participate whenever they liked to and when they were in a neutral mood.

All the background colors used in the experimentation have maximum saturation and brightness levels. This design does not provide the condition for having higher saturated and/or brighter color squares in the foreground. Consequently, brightness and/or saturation contrast having brighter and more saturated foreground colors cannot be obtained. It may be interesting to reverse the experiment by fixating foreground color squares and presenting varying background colors of differing saturation and brightness levels.

The first and second supplementary sets were arranged so that either the columns (brightness-saturation levels) or the rows (hues) were scrolling. The position of a

column or a row was changing on the screen viewed, but the relative position of a column or a row did not change in relation to its neighboring columns and rows. In other words, the column B50 (brightness=50) would always be between B25 and B75. Additional information on the location effect may be attained by randomly assigning the places of the rows and columns in the images viewed.

All the visual stimuli have been presented on a computer monitor. This context may seem like a limitation on the application of the findings. The best results for direct application of the findings are more likely to be obtained in similar presentation mediums such as computer displays, digital mediums, and color television. But, the application of the findings may extend to other mediums of presentation as well. As mentioned in Jackson, MacDonald, and Freeman, there has been a research work at Loughborough University in the UK, under the supervision of Robert W. G. Hunt, which aimed to develop a computer-based model for color appearance, based on the results of extensive psychometric experiments.[22] This model starts with the measured tristimulus values (X, Y, Z) of a color, and calculates the predicted appearance attributes of color, taking into account a range of viewing conditions. All the experimental sessions were conducted using a viewing pattern consisting of a colored test patch surrounded by multiple patches to simulate the diversity of color in a real image. Hunt used many different combinations of viewing parameters. Some of these parameters included various media, such as monitors, prints, transparencies, projection slides, and textiles. This color appearance model suggests a conversion system where

[22] Jackson, MacDonald, and Freeman did not provide any additional information on the date and published references for Hunt's research (71).

color stimulus is converted into perceptual coordinates, taking the viewing conditions as parameters (Jackson, MacDonald, and Freeman 71). Research in this field is promising, thus, opening up the possibility to simulate color combinations of any kind of medium on computer displays and vice versa. Within the scope of recent developments in technology and science, it may be possible to broaden the application range of this dissertation to various mediums.

8 CONCLUSION

The research has dual focus: attention and preference. Throughout the dissertation these two topics were analyzed and discussed separately. The same approach will be maintained in this conclusion chapter for the sake of clarity.

Analyses of data on **attention** showed that brightness and saturation levels are more important than hue component in attracting attention. On every background color, the colored squares having maximum saturation and maximum brightness were found to attract the most attention. It should be noted that all the background colors also had maximum saturation and maximum brightness. Previous studies suggest maximum contrast to be of primary importance, with the condition that the stimulus should be brighter and more saturated than the background (see sec. 3.2). In this study, background and foreground color squares chosen by subjects had the same saturation and brightness levels, both being the maximum. Thus, there is no contrast of either brightness or saturation. It is important to note that this finding does not contradict previous studies since the contrast suggested by them required higher saturation and/or higher brightness level of the foreground stimulus. As the perceived color squares could not have higher brightness or saturation levels than their background, the ones that had the same (which is the maximum level) brightness and saturation level with the background were chosen. This perceptual

elimination of brightness and saturation attributes of color enabled to study the hue effect on various backgrounds in terms of attention.

The red, magenta portion of the visible spectrum has attracted attention to a considerable degree regardless of the background color (30%). Surprisingly, the yellow-green, green, cyan portion of the visible spectrum attracted the attention of 45% of the responses, thus competing with the red, magenta range. Blue (9%), purple (3%), and yellow (3%) rated significantly lower in attracting attention on any background color (see fig. 7.1).

There is no data from past experimental research on color combinations that specify foreground-background color relationships. Thus, research findings of this dual relationship could not be compared with previous studies. The analysis of individual backgrounds is tabulated in table 7.1 in terms of hues that attract the most attention on specified background colors.

The statistical analyses show that location and gender have no significant effect on the choices made for attention in this experiment.

Analyses of data on **preference** demonstrated that all three attributes of color (hue, saturation, and brightness) were important in preferences. Colors having maximum brightness and maximum saturation levels were ranked higher than any other brightness-saturation combination (see table 7.2). Previous experimental studies on

isolated colors also suggested an increase in rated pleasantness with an increase in brightness and saturation (see sec. 4.1).

Blue was the most preferred hue regardless of the background shown (see fig. 7.2). This confirms the findings of previous studies where blue appeared to be a preferred color in isolation (see sec. 4.1). There are only few controlled experimental studies on color combinations that specify foreground-background color relationships in the literature. There are only expert views available on the subject. Thus, research findings could not be examined comparatively with previous studies. Analyses of individual backgrounds are tabulated in terms of hues that are most preferred on specified background colors (see table 7.3).

The statistical tests show that location and gender have no significant effect on the choices made for preference in this experiment.

The findings on attention and preference show low percentages for choices. Although statistically significant, the choices do not extend 45% of the responses of the subject group, and are usually around 20% of the responses. This suggests a variety in attention and preference choices.

Color has always been considered to be linked with subjectivity, especially when preferences are concerned. Culture is always thought to have an influence, as well as gender. There are not enough experimental studies to conclude on the effect of culture or gender. The findings of this dissertation found no gender effect.

Moreover, the general preference for blue, supported findings from different studies having subject groups of various cultures (see secs. 4.1 and 4.2). No matter what the background was, blue was preferred the most. There seems to be a global inclination towards preferring blue regardless of its presented medium. Blue, in many cases, was also verbally stated as the most likeable color when people were asked of their favorite color without any visual stimuli (see secs. 4.1 and 4.2). This finding contradicted with experts' views on color combinations, which formulated numerous color-pairs explaining pleasurable combinations focusing on the hue component of color (see sec. 4.3).

The attributes of brightness and saturation seem to have a great role in attracting attention and in creating pleasurable color combinations in abstract representations. The results demonstrated that foreground colors attracted attention or were preferred when their saturation and brightness levels were increased. The subjects picked up the maximum possible levels available. The literature review suggests brightness and saturation contrasts to be effective in foreground-background color relationships for attention and preference (see chs. 3 and 4). It may be interesting to reverse this experiment and present backgrounds of the same hue with varying brightness and saturation levels to find out on which background a specific color square attracts attention or is preferred more. In this way, contrast relations between background and foreground may be further revealed.

The conclusions of the dissertation presented above should be used with caution, taking into account the limitations and delimitations of the experimental setup, and

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the characteristics of the subject group involved (see sec. 7.3). Some previous studies like Hogg et al. found out that professionals (architects) who were used to work with colored chips were quite consistent in their preferences between the chips and model interiors (231-42). They evaluated colors in the same manner in two different contexts. More and more professionals working with color use computer software to aid their design and/or art; it may be possible through further research to conveniently use color combinations made with computer medium in any desired application.

The present state of knowledge on color combinations is limited. Most research in the field concentrates on what color is. If color is to be applied, it should be specified more in terms of what it is to do. This suggests further studies with color combinations under varying contexts and subjects. With this kind of information, professionals working with colors would both obtain the information needed about the intention of colors, and the freedom to create a solution with various color schemes.

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APPENDICES

APPENDIX A

List of Abbreviations.

Abbreviations for Hues	
H0	Red
H45	Yellow
H90	Yellow-Green
H135	Green
H180	Cyan
H225	Blue
H270	Purple
H315	Magenta

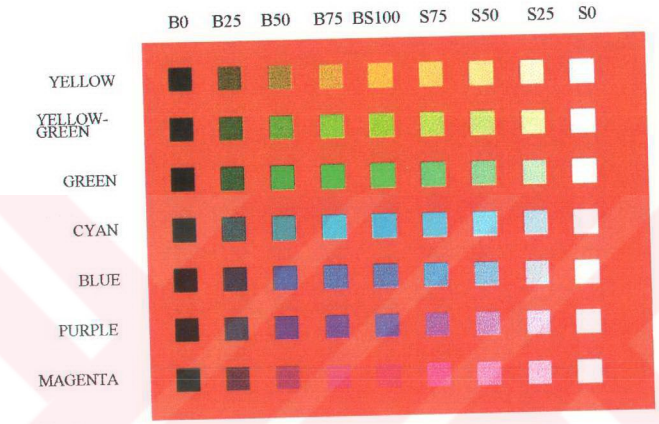
Abbreviations for Brightnesses	
B0	Brightness 0%, Saturation 100%, (Black)
B25	Brightness 25%, Saturation 100%
B50	Brightness 50%, Saturation 100%
B75	Brightness 75%, Saturation 100%
BS100	Brightness 100%, Saturation 100%

Abbreviations for Saturations	
S0	Saturation 0%, Brightness 100%, (White)
S25	Saturation 25%, Brightness 100%
S50	Saturation 50%, Brightness 100%
S75	Saturation 75%, Brightness 100%
BS100	Saturation 100%, Brightness 100%

APPENDIX B

Images that were Presented During the Experimentation.

APPENDIX B.1- The Main Image Set.



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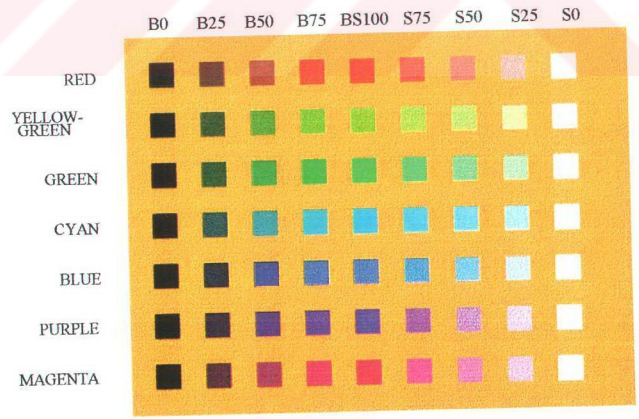
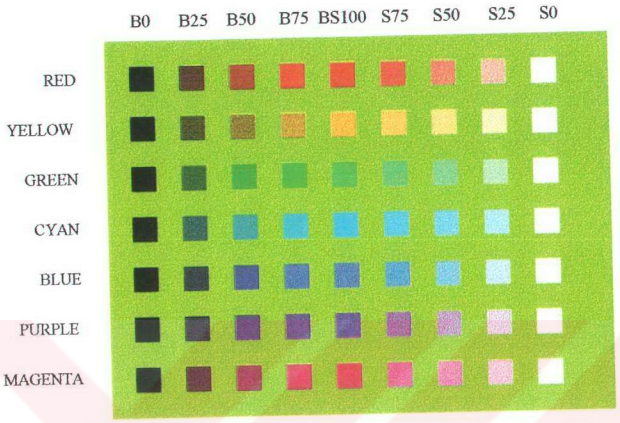
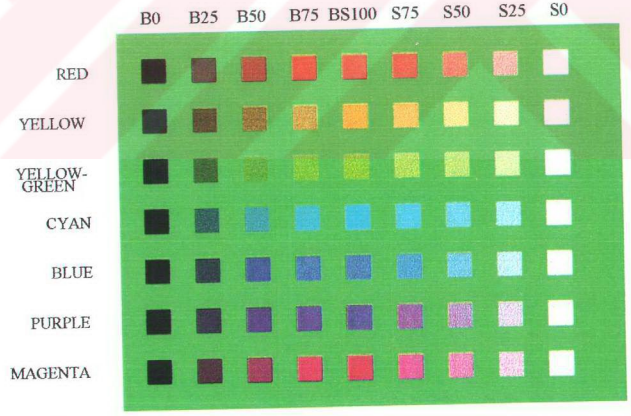


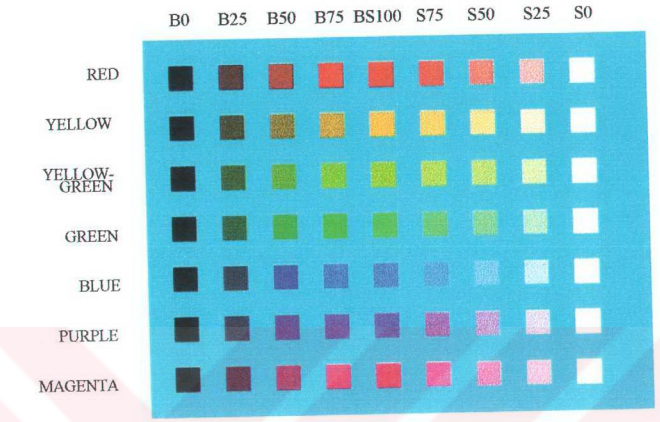
Yellow Background



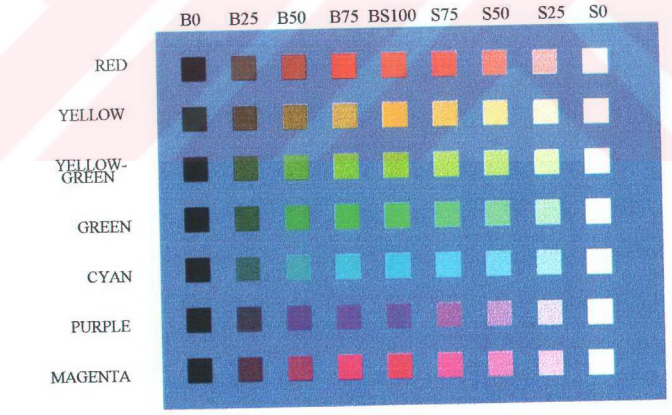
Yellow-Green Background



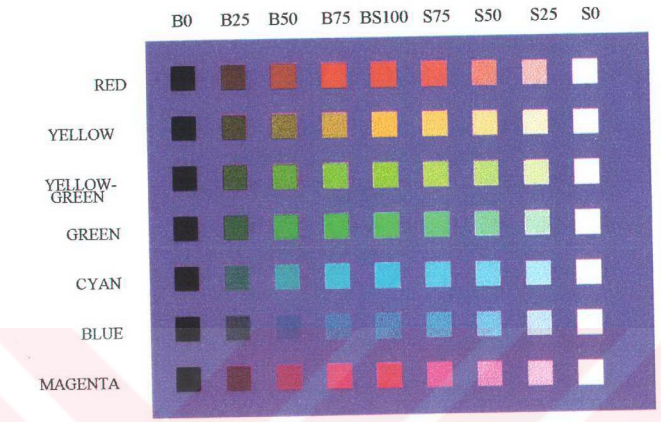
Green Background



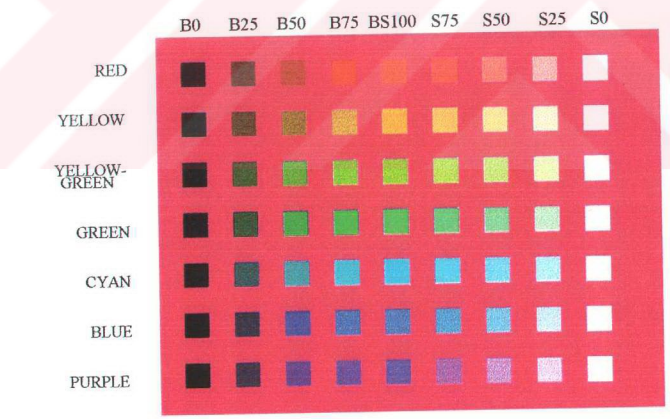
Cyan Background



Blue Background

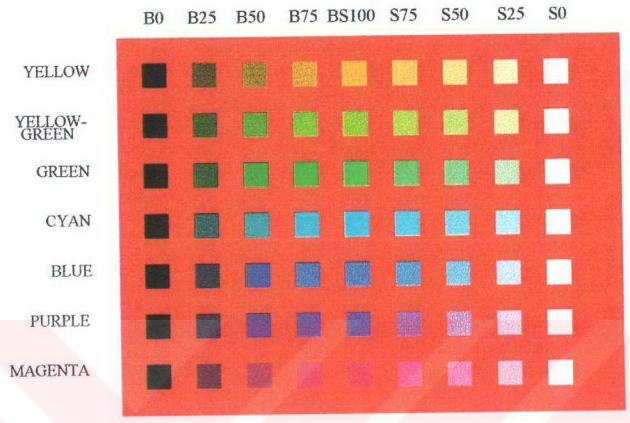


Purple Background



Magenta Background

APPENDIX B.2- The First Supplementary Image Set (scrolling down).



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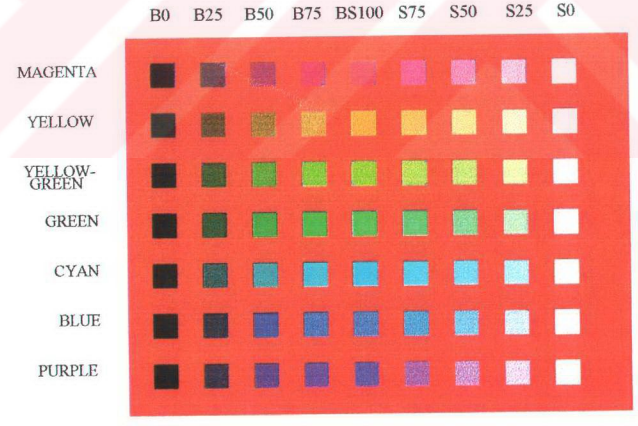
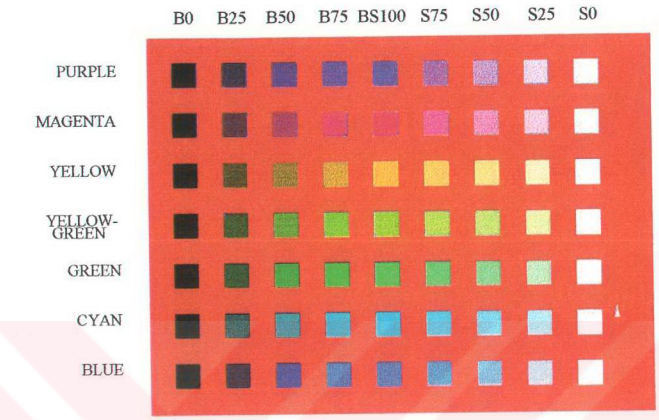


Red Background/ 2nd Image



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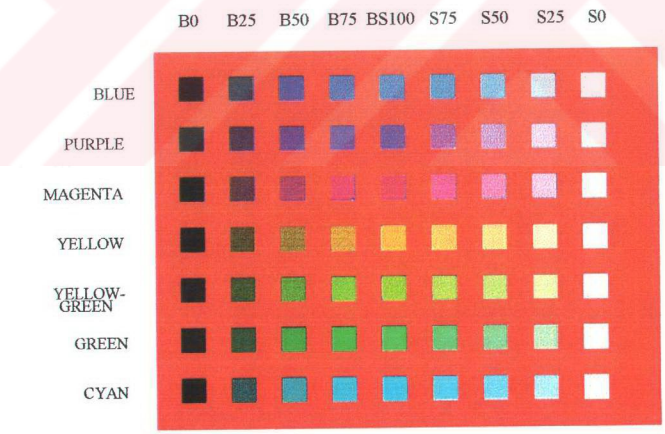

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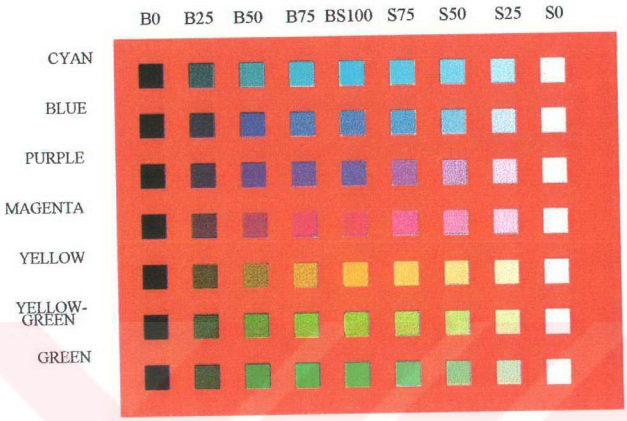

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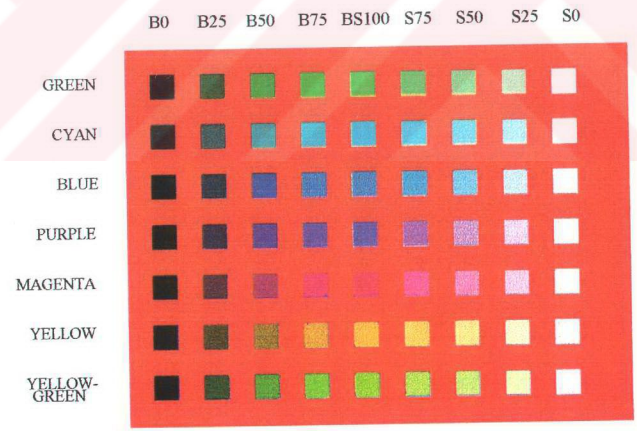
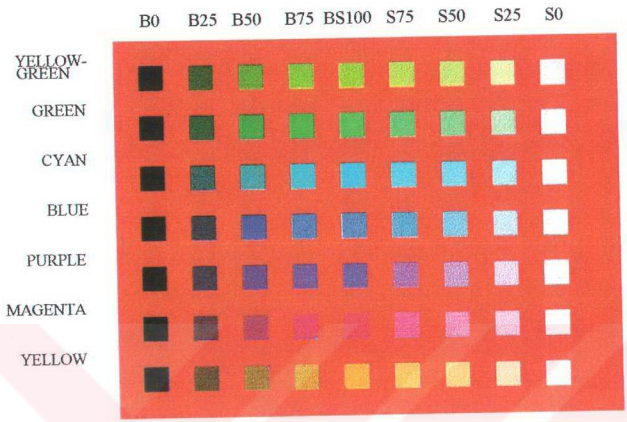
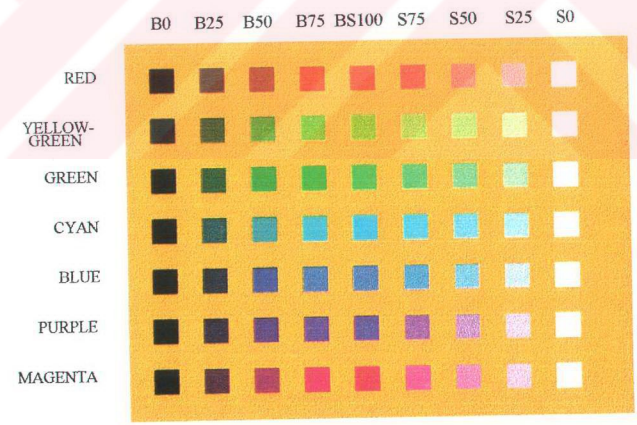


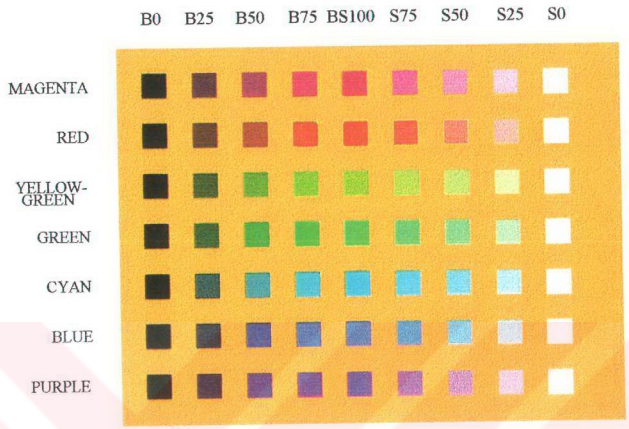
Red Background/ 6th Image



Red Background/ 7th Image



Yellow Background/ 1st Image



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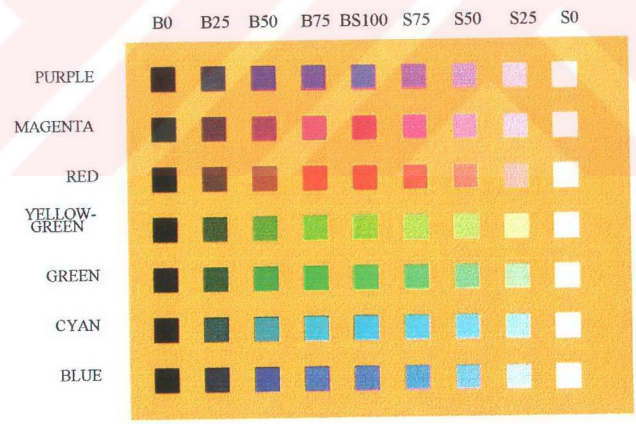

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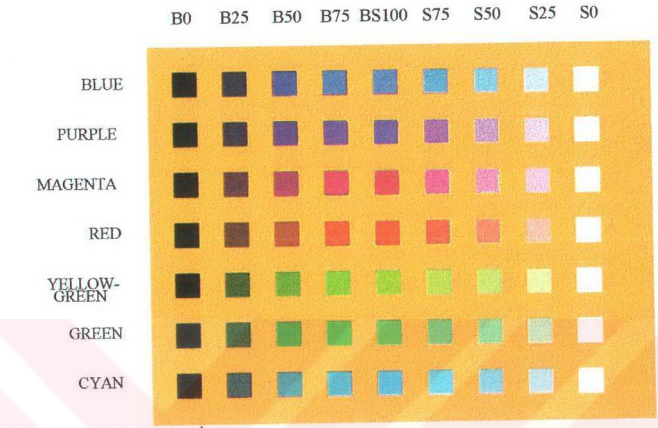

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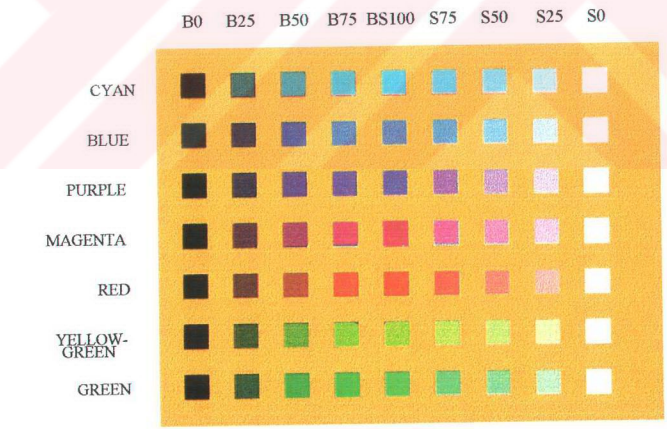

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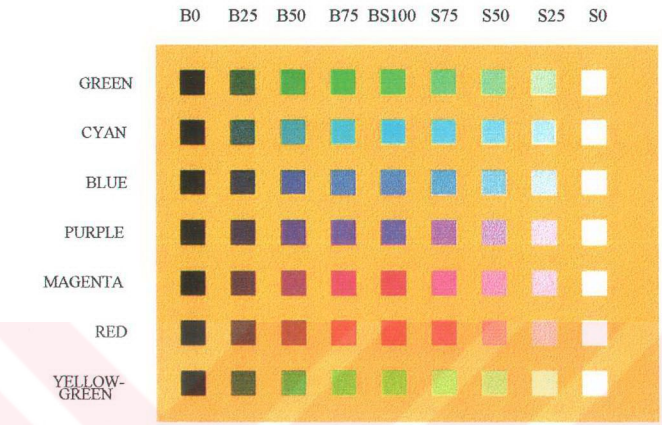

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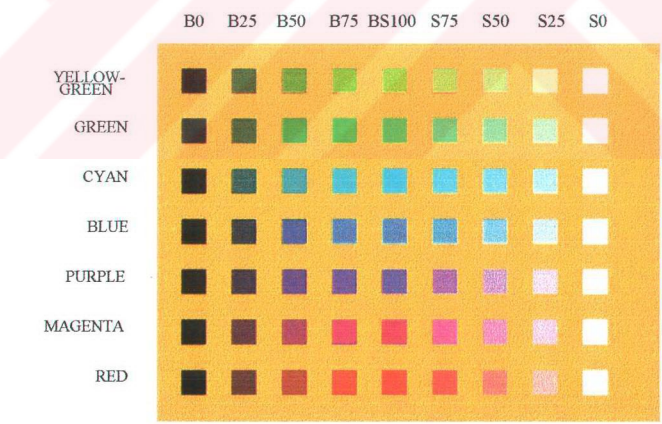

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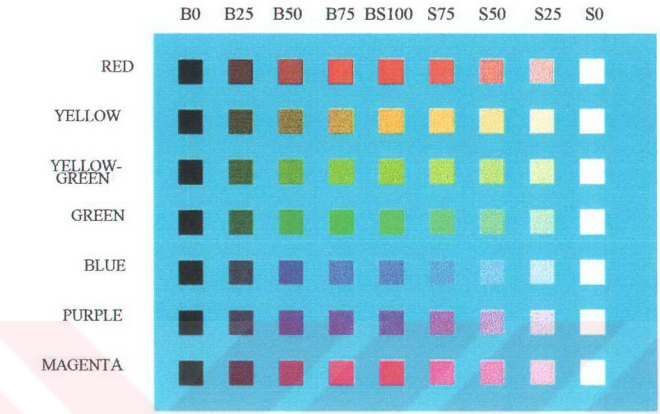

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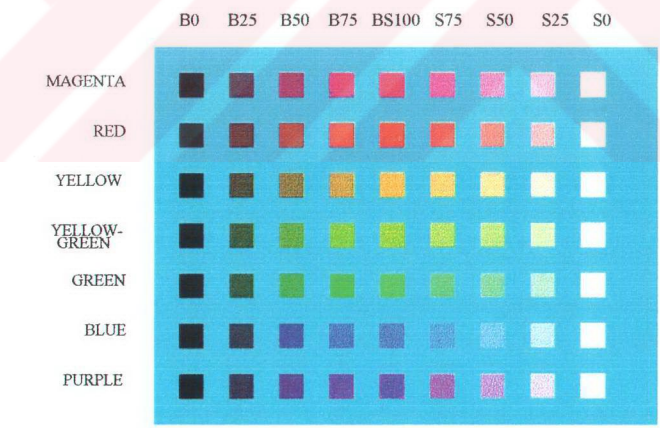

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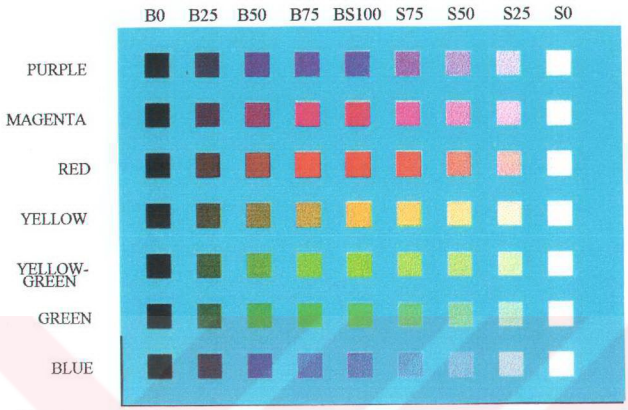

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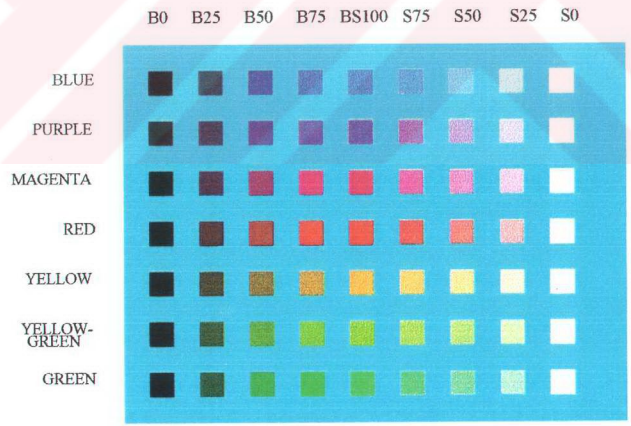
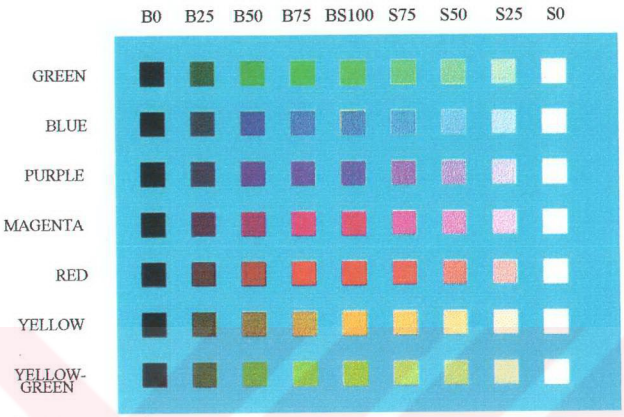
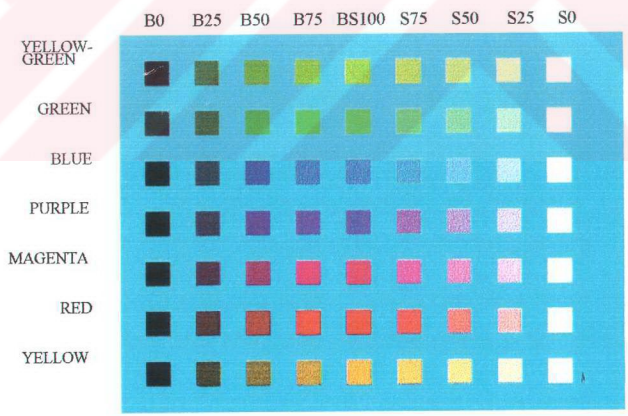


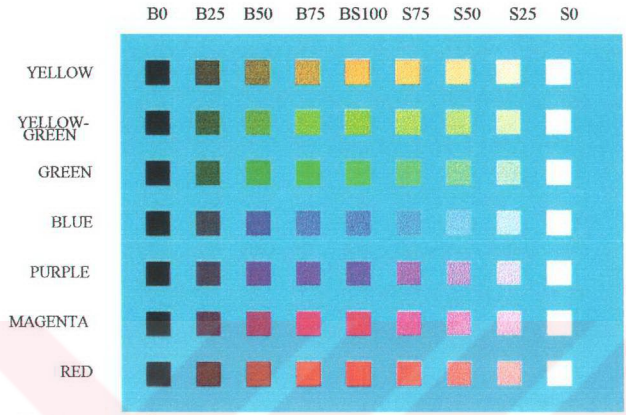
Cyan Background/ 4th Image



Cyan Background/ 5th Image



Cyan Background/ 6th Image



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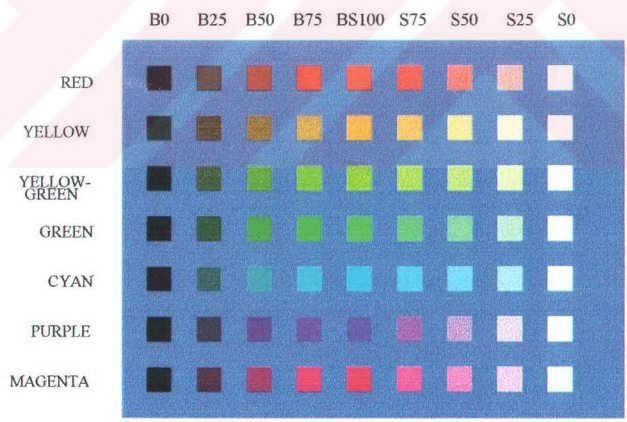
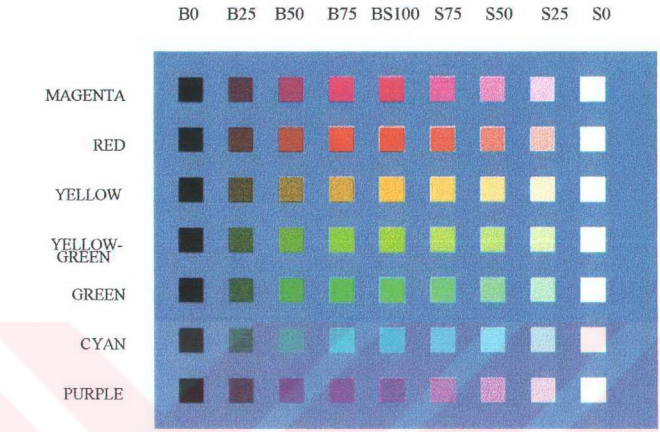
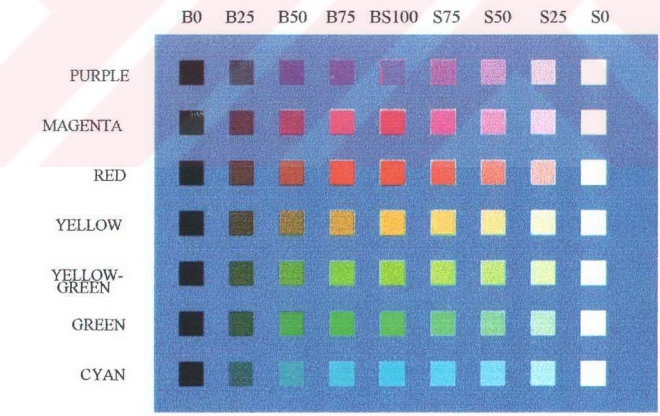


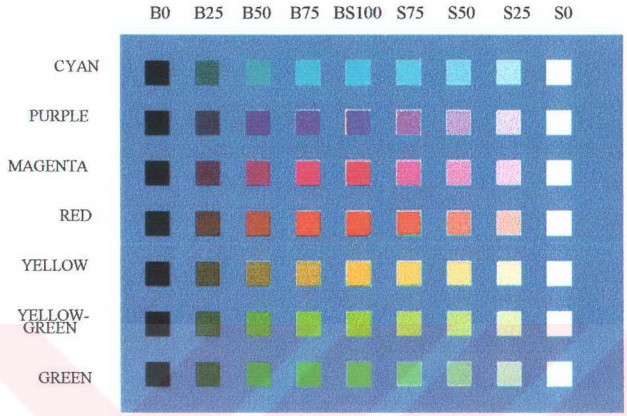
Blue Background/ 1st Image



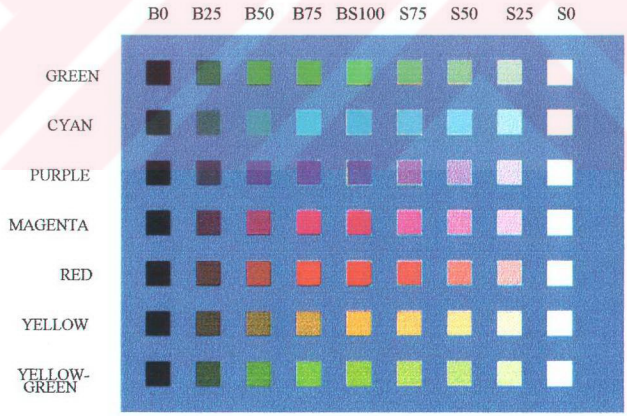
Blue Background/ 2nd Image



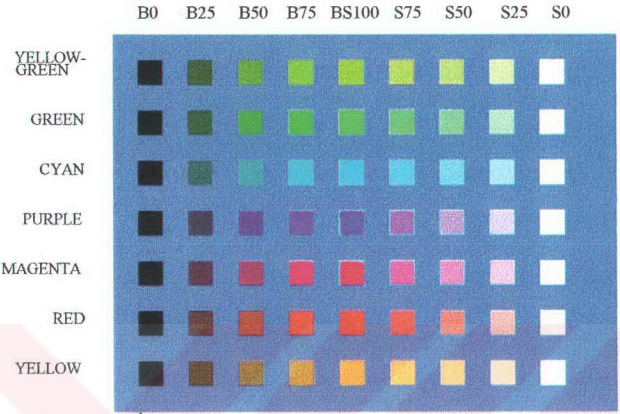
Blue Background/ 3rd Image



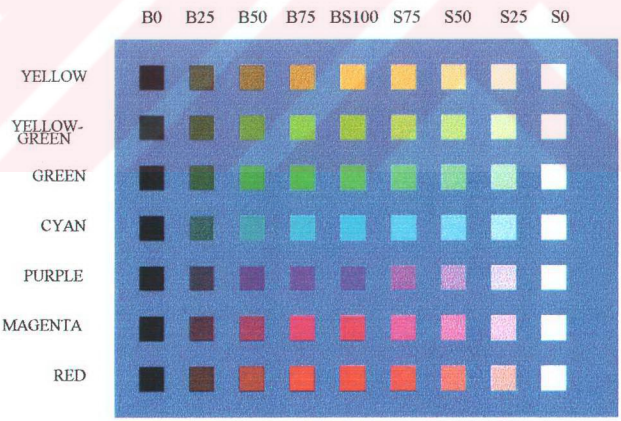
Blue Background/ 4th Image



Blue Background/ 5th Image

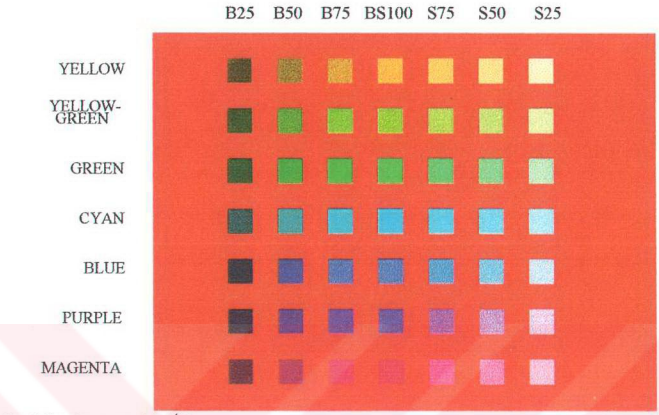


Blue Background/ 6th Image

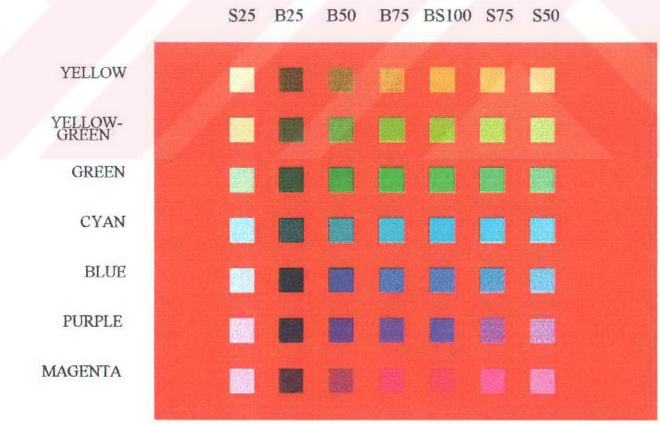


Blue Background/ 7th Image

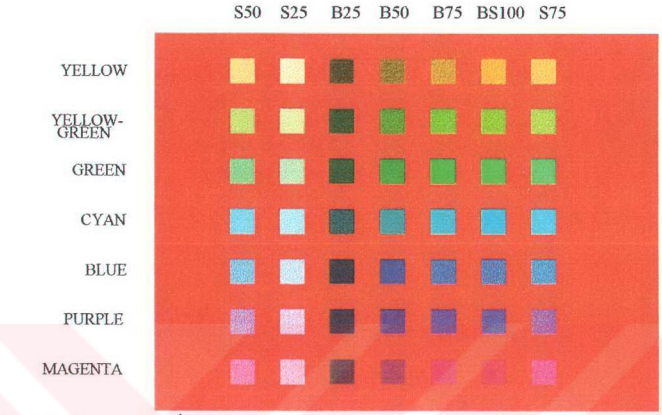
APPENDIX B.3- The Second Supplementary Image Set (Scrolling to the right).



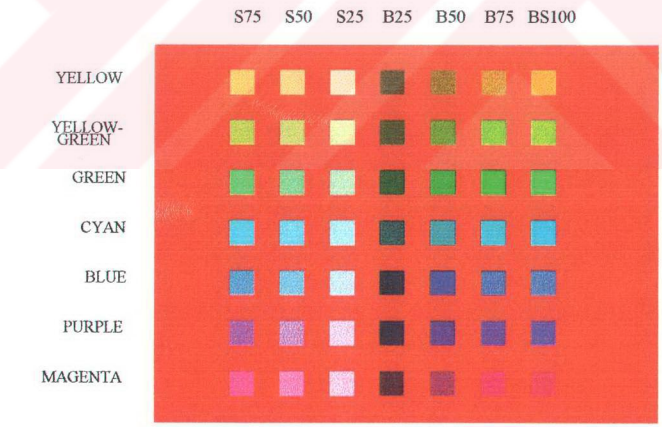
Red Background/ 1st Image



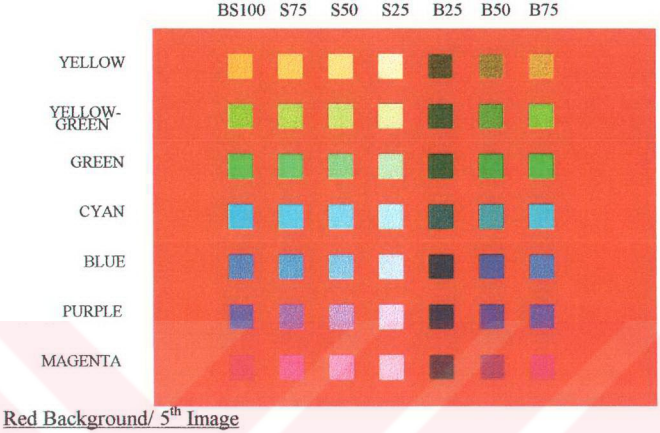
Red Background/ 2nd Image



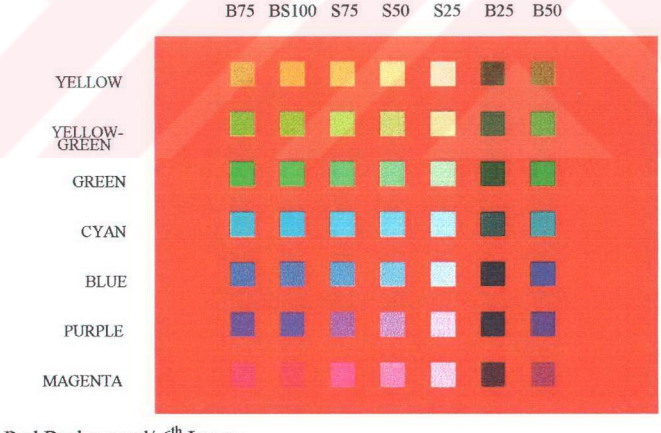
Red Background/ 3rd Image



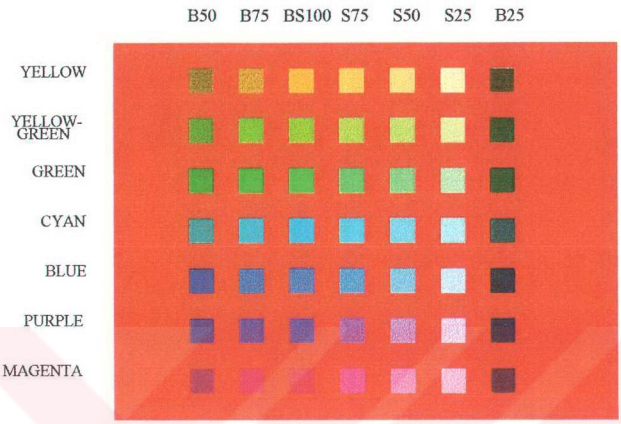
Red Background/ 4th Image



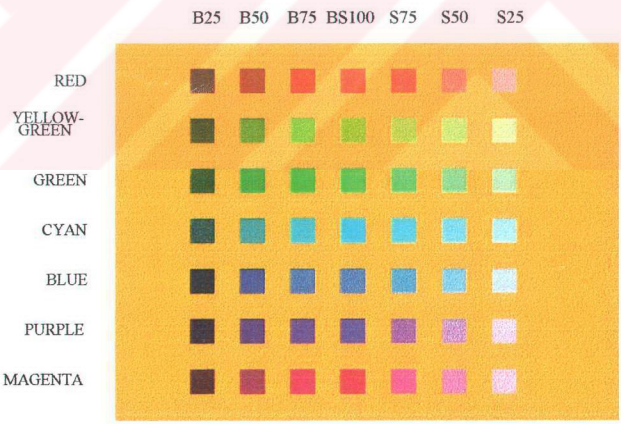
Red Background/ 5th Image



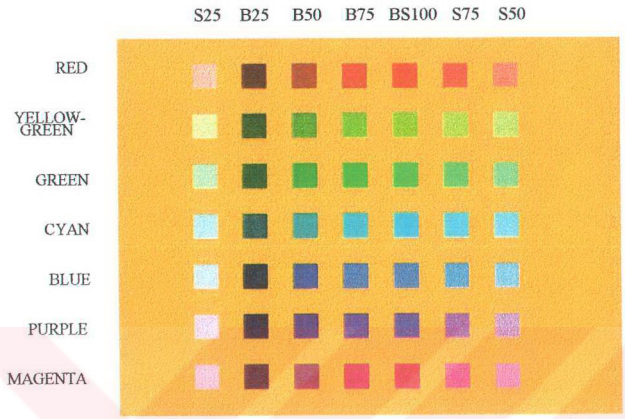
Red Background/ 6th Image



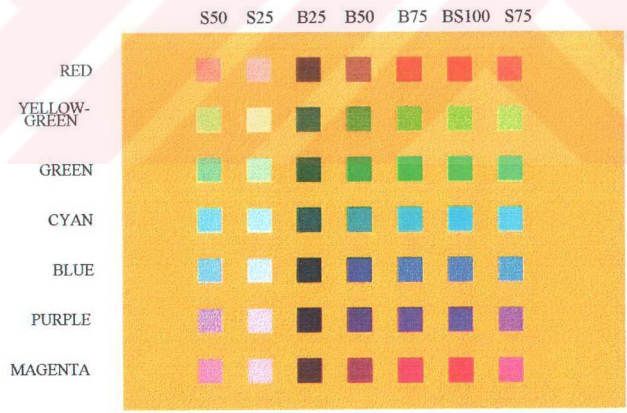
Red Background/ 7th Image



Yellow Background/ 1st Image



Yellow Background/ 2nd Image



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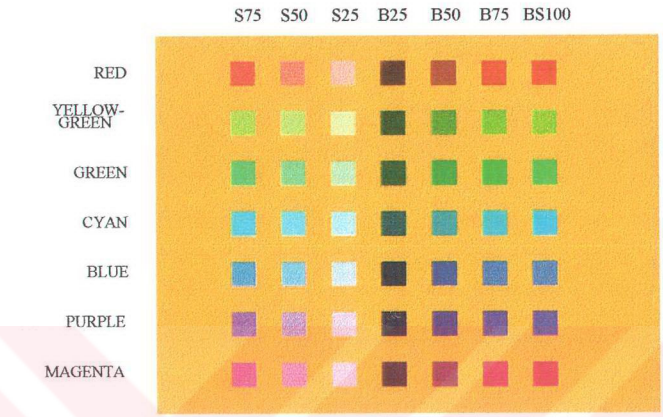
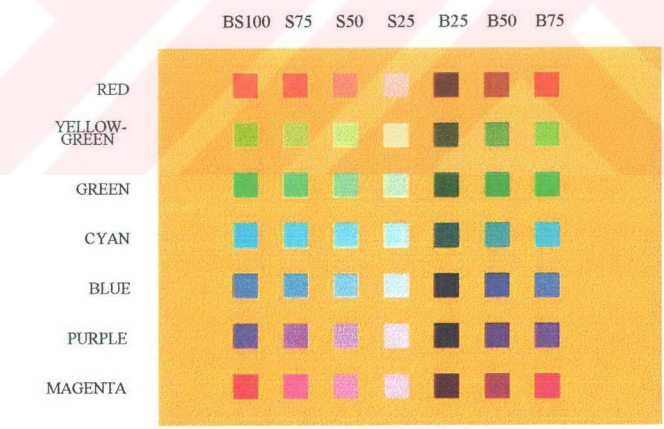
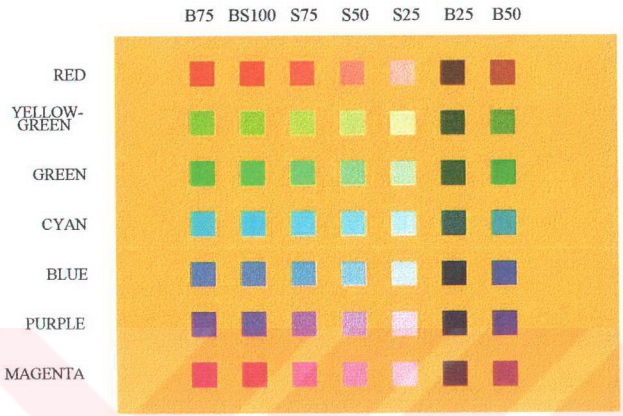


Yellow Background/ 4th Image



Yellow Background/ 5th Image



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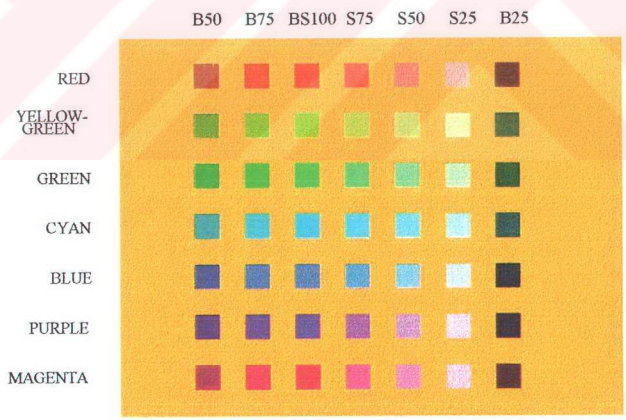
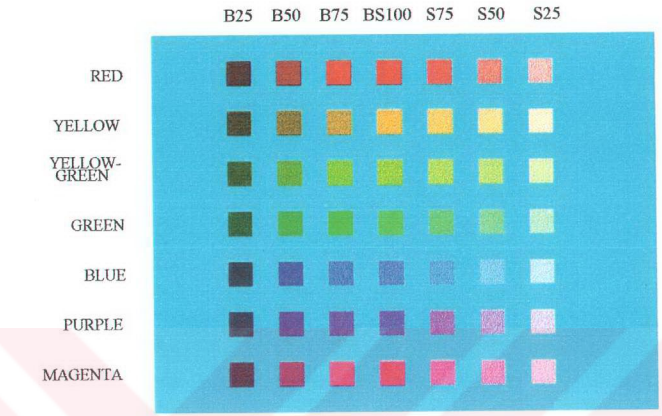
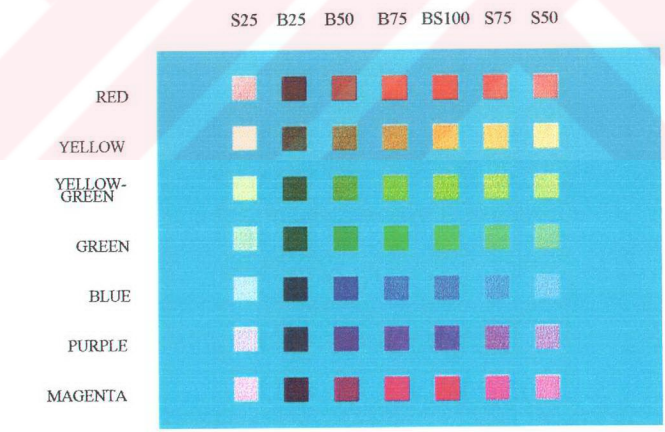


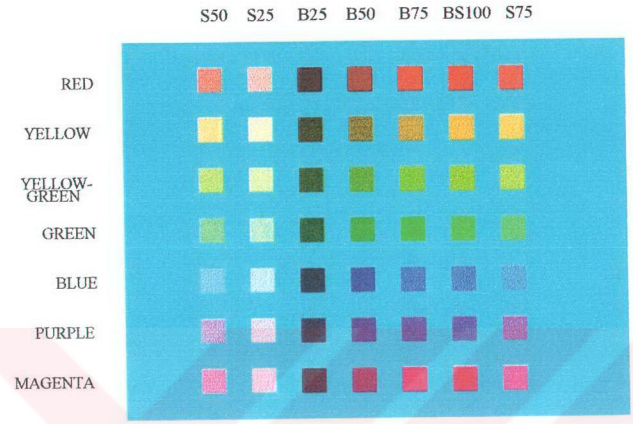
Yellow Background/ 7th Image



Cyan Background/ 1st Image



Cyan Background/ 2nd Image



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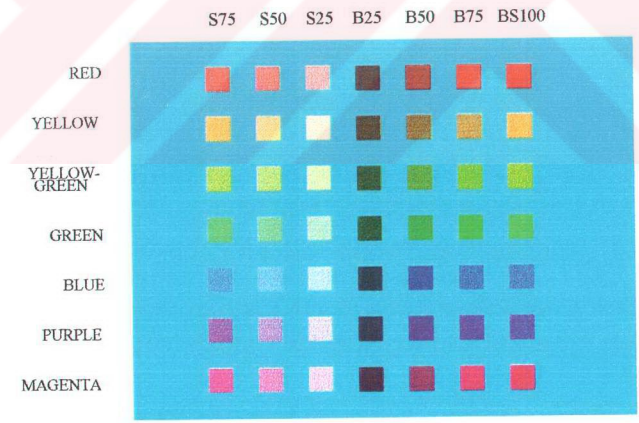
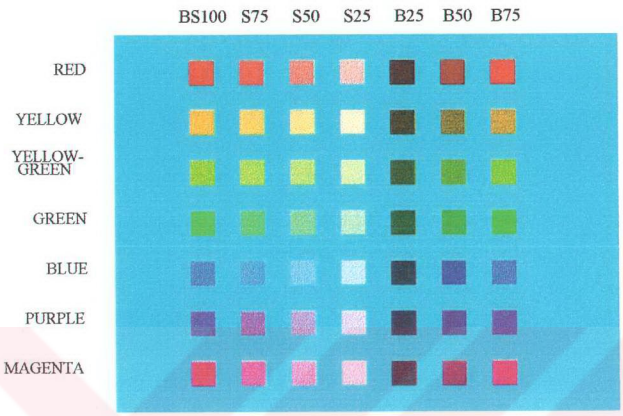
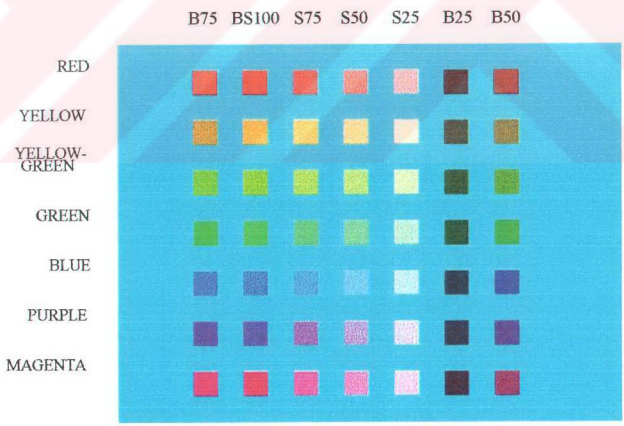


Cyan Background/ 4th Image



Cyan Background/ 5th Image



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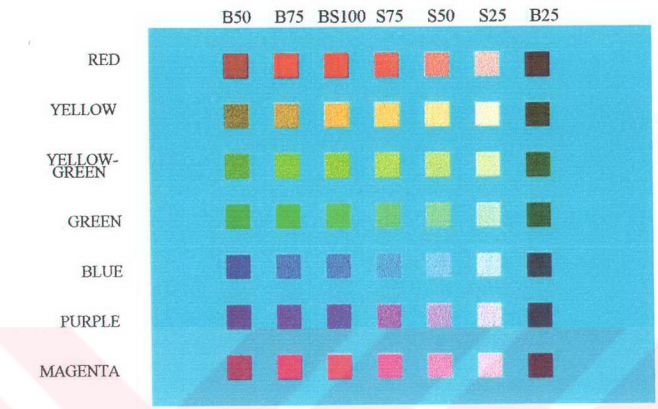
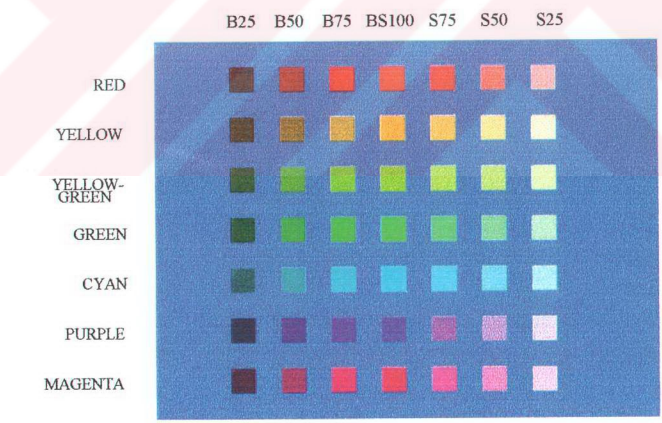
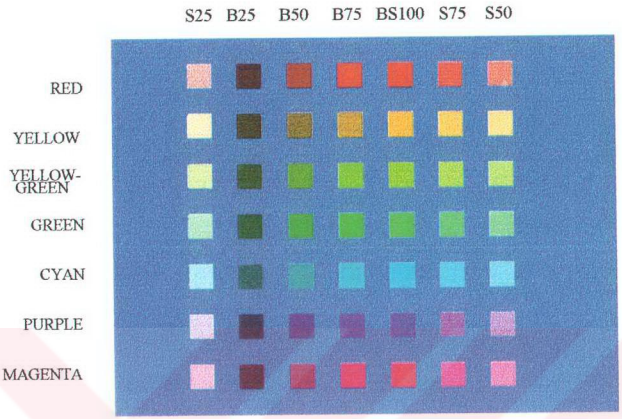


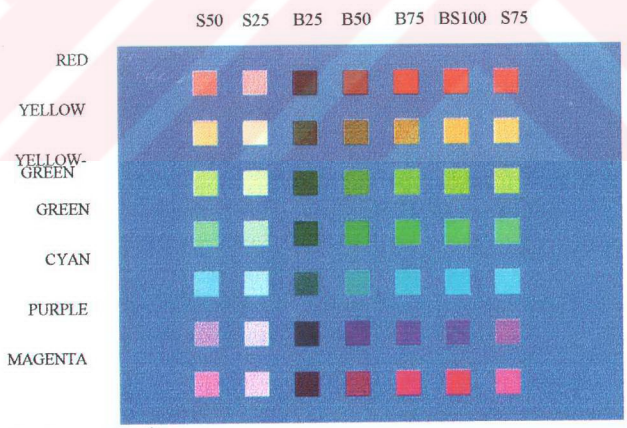
Cyan Background/ 7th Image



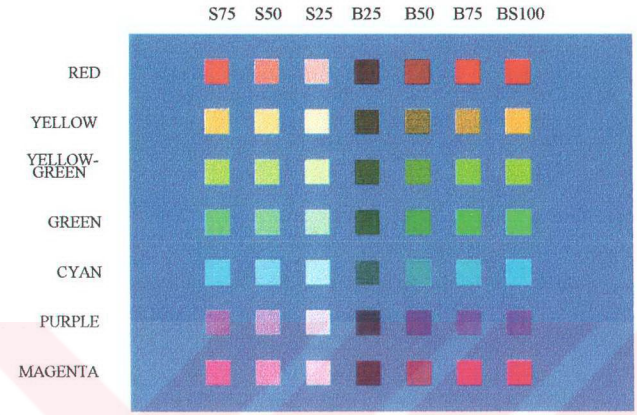
Blue Background/ 1st Image



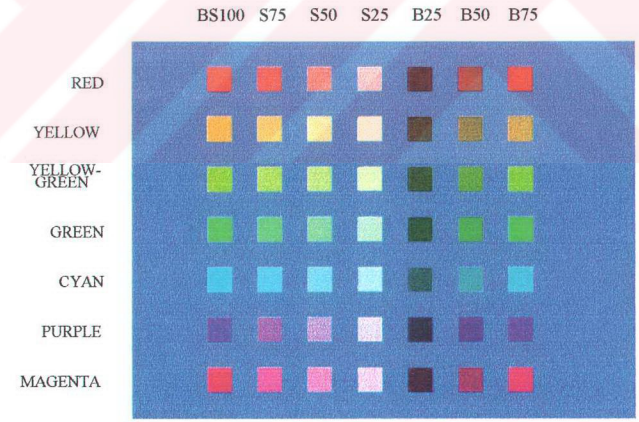
Blue Background/ 2nd Image



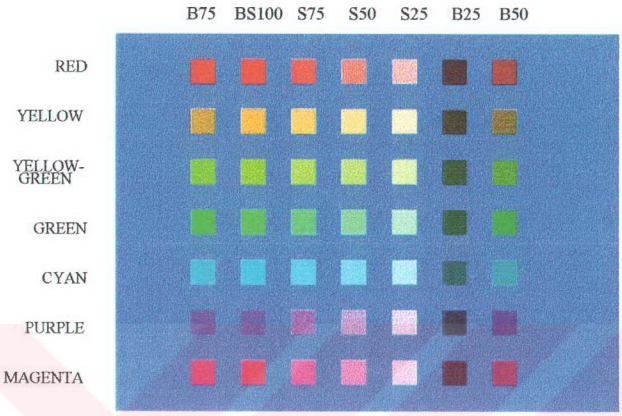
Blue Background/ 3rd Image



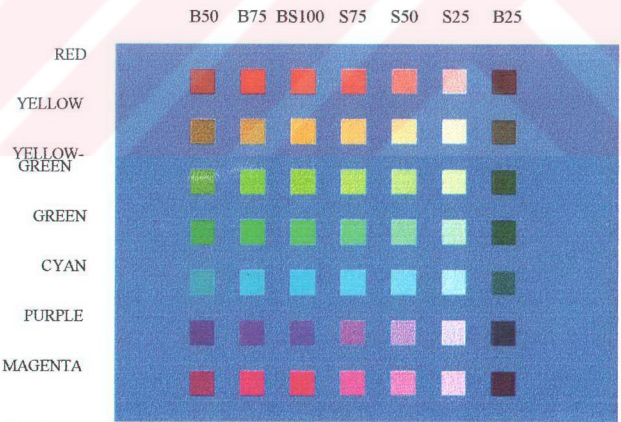
Blue Background/ 4th Image



Blue Background/ 5th Image

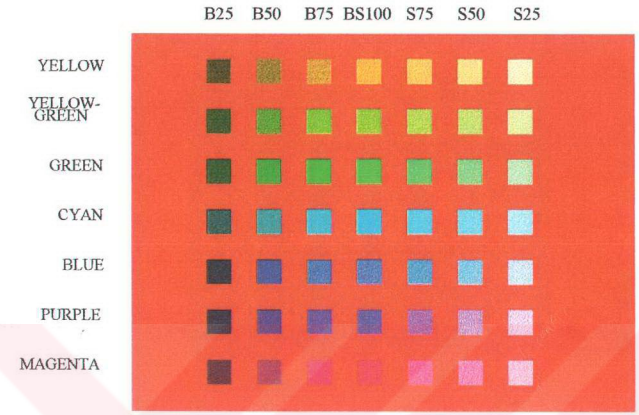


Blue Background/ 6th Image



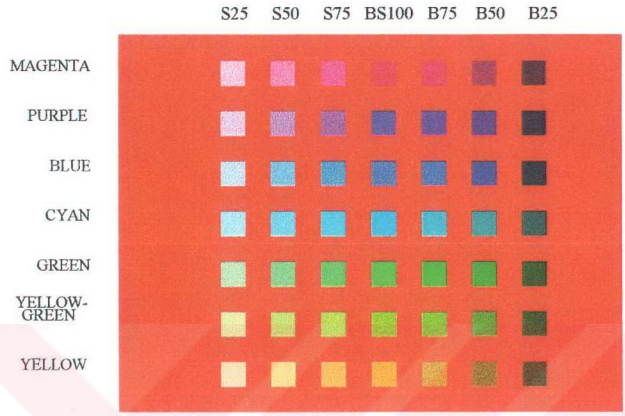
Blue Background/ 7th Image

APPENDIX B.4- The Third Supplementary Image Set (Rotating).

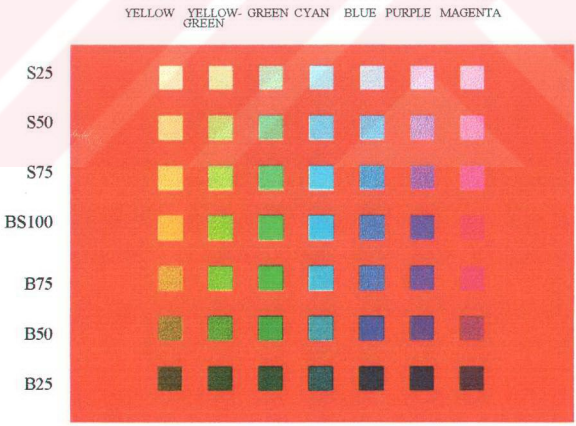


Red Background/ 1st Image

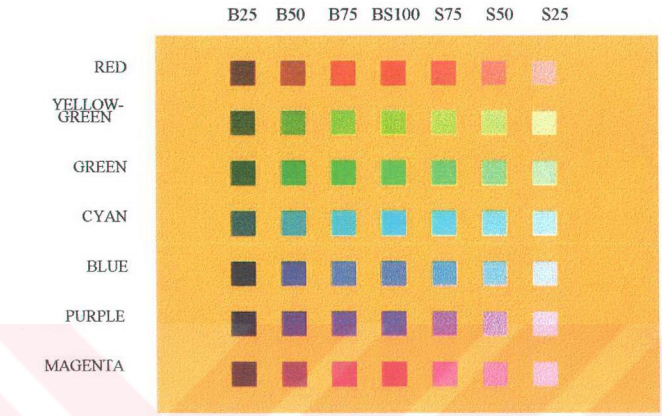
Red Background/ 2nd Image



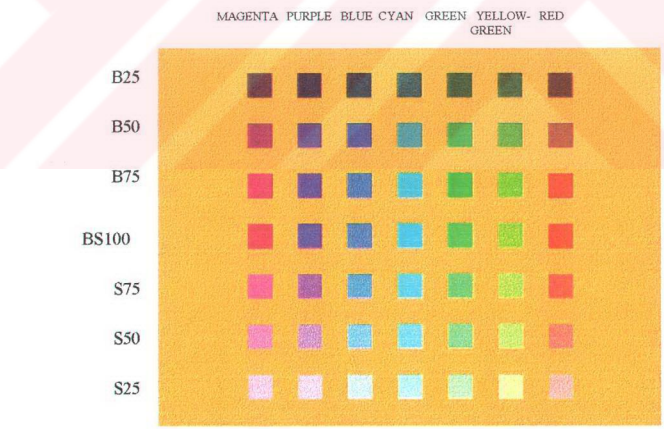
Red Background/ 3rd Image



Red Background/ 4th Image



Yellow Background/ 1st Image



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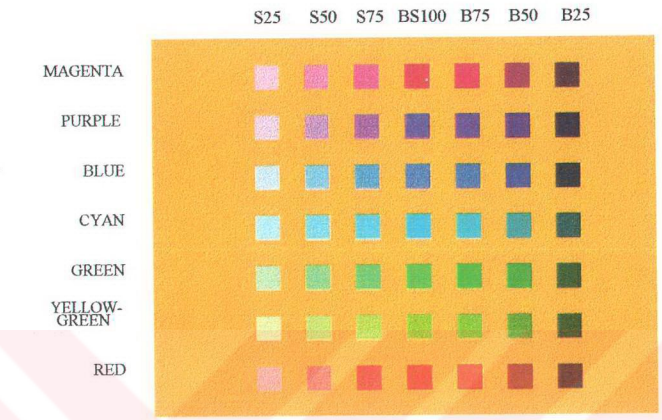
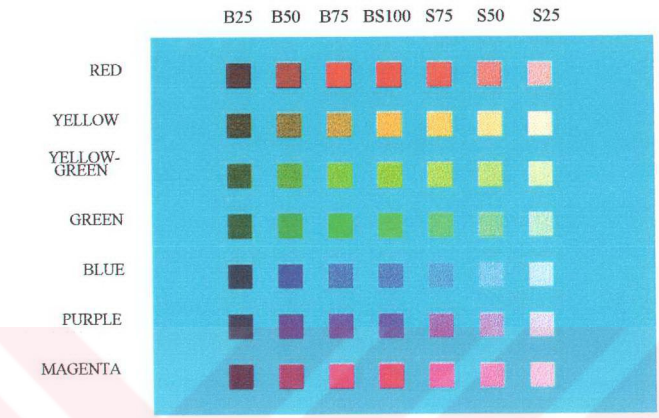
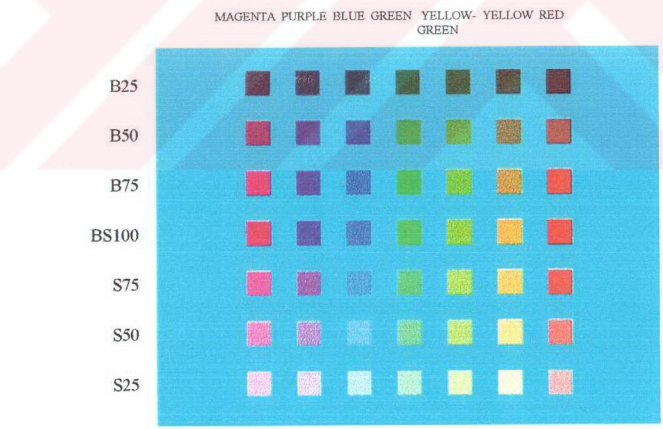


Yellow Background/ 3rd Image

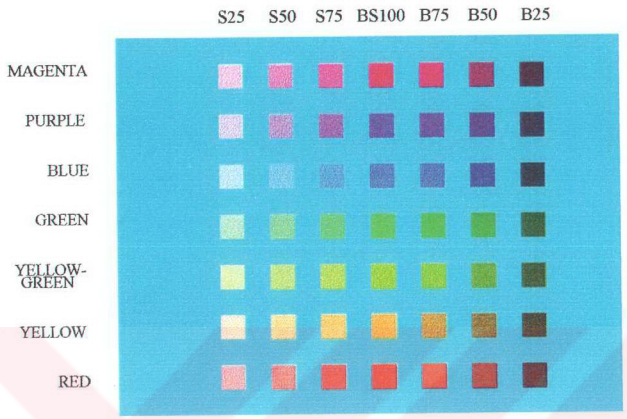
Yellow Background/ 4th Image



Cyan Background/ 1st Image

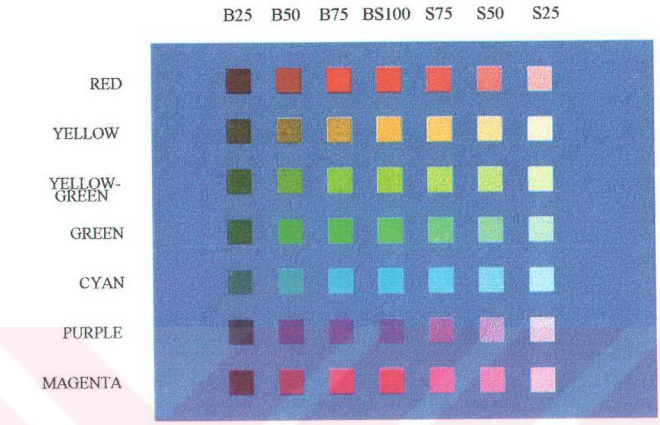


Cyan Background/ 2nd Image

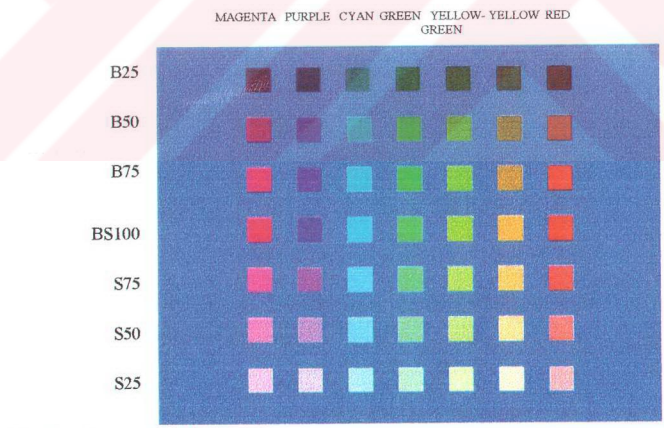


Cyan Background/ 3rd Image

Cyan Background/ 4th Image



Blue Background/ 1st Image



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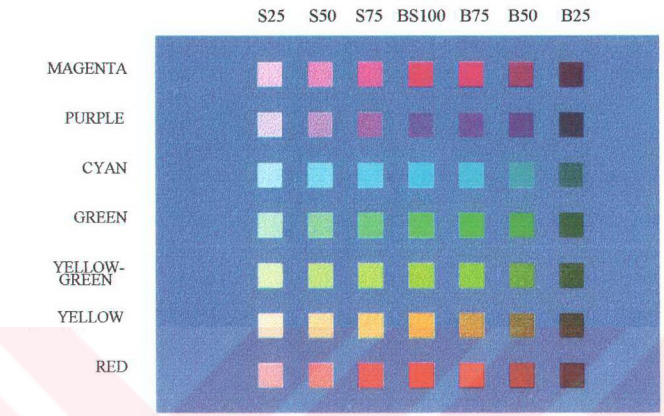

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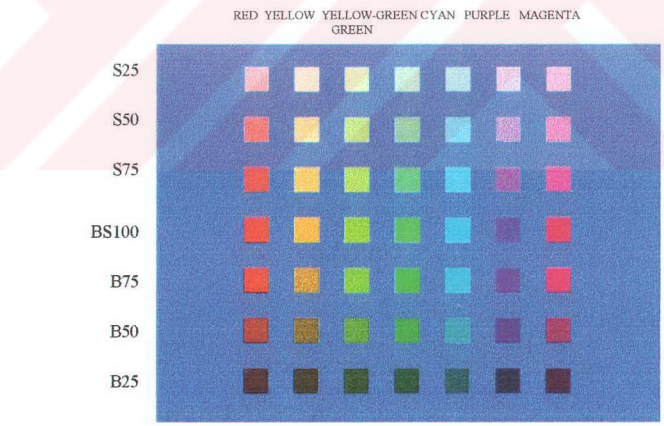

Blue Background/ 4th Image

APPENDIX C

The Questionnaire and the Data Sheets.

APPENDIX C.1- The Questionnaire (in Turkish).

ANKET

Renk algılaması ile ilgili bir çalışma yapmaktayız. Görüşleriniz bizim için önem taşımaktadır. Bu anket Bilkent Üniversitesi, Güzel Sanatlar, Tasarım ve Mimarlık Fakültesi bünyesindeki bir doktora tezine veri toplamak amacı ile hazırlanmıştır. Anket sonuçlarından bilimsel veriler elde edileceği için lütfen soruları dikkatle cevaplayınız. TEŞEKKÜR EDERİZ.

AŞAĞIDAKİ SORULARI SİZİN İÇİN EN UYGUN OLAN ŞEKİLDE CEVAPLAYINIZ:

1. Adınız, Soyadınız:
2. Yaşınız:
3. Cinsiyetiniz: K E
4. Öğrencisi olduğunuz bölüm:
   Devam etmekte olduğunuz sınıf:
5. Eğitim geçmişiniz:

Eğitim Kurumu	Hangi İl/ İllerde okudunuz	Okunulan Süre/ Süreler
İlköğrenim (İlkokul)		
Ortaöğrenim (Ortaokul-Lise)		
Yükseköğrenim (Üniversite)		
Yüksek Lisans (Master-Doktora)		

6. Herhangi bir göz bozukluğunuz var mı? Varsa açıklayınız lütfen.
7. Bu göz bozukluğunuzu giderecek herhangi bir araç (lens, gözlük, v.b. gibi) kullanıyor musunuz ? Bu araç şu an üzerinizde mi?

8. Üniversite eğitiminiz süresince dolaylı da olsa renk ile ilgili bir eğitim ya da ders aldınız mı? Aldınızsa eğitimin türünü, süresini ve yerini belirtiniz.

9. Ortaöğrenim (ortaokul/lise) kurumlarında dolaylı da olsa renk ile ilgili bir eğitim ya da ders aldınız mı? Aldınızsa eğitimin türünü, süresini ve yerini belirtiniz.

10. Eğitim kurumları harici bir yerde dolaylı da olsa renk ile ilgili bir eğitim ya da ders aldınız mı? Aldınızsa eğitimin türünü, süresini ve yerini belirtiniz.

11. Renk ile ilgili herhangi bir uğrasınız var mı ya da oldu mu? Olduysa lütfen türünü, süresini ve yerini belirtiniz.

12. Yaşadığınız ortamlarda genel olarak nasıl bir renk çeşitliliği var?
    a. Çok ve çeşitli renk kombinasyonları mevcut.
    b. Renk çeşitliliği az.
    c. Farkında değilim/ Bilmiyorum.

13. Renk tercihlerimde:
    a. Tutucuyum (hep sevdiğim ve kullandığım bazı renkler vardır).
    b. Değişkenim (renk kullanımı tercihlerim değişir/ modayı takip ederim).
    c. Renk tercihleri benim için önemli değildir/ İlgilenmem.
    d. Renk tercihlerini başkalarına bırakırım.

TEŞEKKÜR EDERİZ

APPENDIX C.2- Back Page of the Questionnaire (in Turkish).

Kalibrasyon:

	Attention / Dikkat		Preference / Tercih	
	Time / Zaman	Choice / Seçim	Time / Zaman	Choice / Seçim
0^0				
45^0				
90^0				
135^0				
180^0				
225^0				
270^0				
315^0				

Araştırmacının adı: Nilgün Camgöz
Yer: Çevre Laboratuvarı, Bilkent Üniversitesi, Ankara – Türkiye.
Tarih:
Saat:
Anket no:
Video kaset no:
Renk körlüğü: Vardır Yoktur

APPENDIX C.3- The Questionnaire (translated to English).

QUESTIONNAIRE

This is a study on color perception. Your responses are important for this study. This questionnaire is designed to gather data for a Ph.D. Dissertation prepared at Bilkent University, Faculty of Fine Arts, Design and Architecture. Responses to this experiment are analyzed as scientific data, for this reason please answer the questions carefully. THANK YOU.

ANSWER THE QUESTIONS APPROPRIATE TO YOUR SITUATION:

1. Given name, Family name:
2. Age:
3. Gender: F M
4. The department you are attending to:
   The grade you are in:
5. Educational Background:

Educational Institute	City/ Cities you have attended the institute	Duration of Attendance
Primary Education (Primary School)		
Secondary Education (Secondary-High School)		
Higher Education (University)		
Graduate Studies (Masters-Ph.D.)		

6. Do you have any eye or vision deficiencies? If yes, please explain.
7. Do you use any correction equipment (contact lenses, eyeglasses, etc.) for any eye or vision deficiency you have? Are you wearing this equipment at the moment?
8. Have you had any courses or training related to color during your university education? If yes, indicate its type, duration and place.
9. Have you had any courses or training related to color during your secondary education (secondary/high school)? If yes, indicate its type, duration and place.
10. Have you had any courses or training related to color outside educational institutes? If yes, indicate its type, duration and place.
11. Do you have any hobbies related to color? If yes, indicate its type, duration and place.
12. What type of color variety do you observe in the environments you live in?
    a. A variety of color combinations are present.
    b. Color variety is few.
    c. I am not aware/ I do not know.
13. In my color preferences, I am:
    a. Conservative (I have colors that I always like and use).
    b. Changing (My color preferences are changeable/ I follow color trends).
    c. Color preferences are not important to me/ I do not care.
    d. I let others to decide for me.

THANK YOU

APPENDIX C.4- Back Page of the Questionnaire (translated to English).

Calibration:

	Attention		Preference	
	Time	Choice	Time	Choice
0^0				
45^0				
90^0				
135^0				
180^0				
225^0				
270^0				
315^0				

Name of the researcher: Nilgün Camgöz
Location: Environmental Laboratory, Bilkent University, Ankara – Turkey.
Date:
Time:
Questionnaire no:
Video tape no:
Color deficiency: Has Has Not

APPENDIX C.5 Data Sheet for Supplementary Image Sets (scrolling down, scrolling to the right, and rotating sets).

Name: Questionnaire no:

	Fon/ Background		Fon/ Background	
Görüntüler/Images	Dikkat/ Att.	Tercih/ Pref.	Dikkat/ Att.	Tercih/ Pref.
1				
2				
3				
4				
5				
6				
7				

	Fon/ Background		Fon/ Background	
Görüntüler/Images	Dikkat/ Att.	Tercih/ Pref.	Dikkat/ Att.	Tercih/ Pref.
1				
2				
3				
4				

APPENDIX D

Description of the Subject Group.

AGE	Subjects	Percent
<20	10	8%
20-24	**96**	**78%**
25-30	14	11%
≥30	3	3%
	123	*100%*

GENDER	Subjects	Percent
Male	50	41%
Female	73	59%
	123	*100%*

DEPARTMENT	Subjects	Percent
IAED	**100**	**81%**
GRA	10	8%
LAUD	13	11%
	123	*100%*

IAED: Interior Architecture and Environmental Design.
GRA: Graphic Design.
LAUD: Landscape Architecture and Urban Design.

GRADE	Subjects	Percent
1	12	10%
2	**68**	**55%**
3	16	13%
4	10	8%
Graduate Students	17	14%
	123	*100%*

COLOR EDUCATION	Subjects	Percent
N	9	7%
S	**80**	**65%**
M	34	28%
	123	*100%*

N/None: Has not have any education on color.
S/Some: Has taken courses distantly related to color for less than three years.
M/Much: Has taken intense courses related to color for at least three years.

COLOR INTEREST	Subjects	Percent
S	32	26%
G	**84**	**68%**
N	7	6%
	123	*100%*

S/Special: Has extracurricular interest/activities on color.
G/General: Has no extracurricular activities on color/ interested in the scope of schoolwork.
N/Not interested: Has no interest at all in color related subjects.

CITY OF DWELLING	Subjects	Percent
ADANA	2	1.5%
ANKARA	**94**	**76%**
AYDIN	1	1%
BURSA	3	2%
ERZURUM	1	1%
GİRESUN	1	1%
İSTANBUL	6	5%
İZMİR	9	7%
İZMİT	1	1%
KONYA	1	1%
MERSİN	2	1.5%
SAMSUN	1	1%
VAN	1	1%
	123	*100%*

APPENDIX E

Data Structures: Tabulated Response Distributions.

APPENDIX E.1- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and Hue Effect in Attention.

Red Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H45	1	0	0	0	4	0	0	0	1	*6*
H90	0	0	1	0	7	0	0	0	0	*8*
H135	0	0	2	2	24	1	0	0	0	*29*
H180	0	1	0	1	33	4	0	0	1	*40*
H225	0	1	2	4	15	3	0	0	0	*25*
H270	0	0	1	1	0	2	0	0	1	*5*
H315	0	0	1	0	7	0	0	0	0	*8*
Sum	*1*	*2*	*7*	*8*	*90*	*10*	*0*	*0*	*3*	***121***

Yellow Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	3	0	0	3	14	1	0	0	2	*23*
H90	0	0	1	0	3	0	0	0	0	*4*
H135	0	0	1	0	8	0	0	0	1	*10*
H180	1	0	0	1	39	3	3	3	0	*50*
H225	0	0	1	3	10	0	0	0	0	*14*
H270	0	1	3	0	0	0	0	0	0	*4*
H315	1	0	1	4	10	0	0	0	0	*16*
Sum	*5*	*1*	*7*	*11*	*84*	*4*	*3*	*3*	*3*	***121***

T.C. YÜKSEKÖĞRETİM KURULU
DOKÜMANTASYON MERKEZİ

Yellow-Green Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	2	0	1	0	19	0	0	0	1	*23*
H45	0	0	1	1	2	0	0	0	0	*4*
H135	0	0	0	0	1	0	0	0	0	*1*
H180	0	0	0	2	25	5	2	0	2	*36*
H225	0	1	2	3	9	0	0	1	0	*16*
H270	0	0	1	1	1	1	0	1	1	*6*
H315	2	0	2	5	20	3	0	0	3	*35*
Sum	*4*	*1*	*7*	*12*	*77*	*9*	*2*	*2*	*7*	***121***

Green Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	3	0	2	0	20	0	2	0	2	*29*
H45	0	0	0	1	0	0	0	0	0	*1*
H90	0	0	1	1	3	3	0	1	0	*9*
H180	0	0	1	2	25	0	1	1	1	*31*
H225	0	0	1	2	8	1	0	0	0	*12*
H270	0	0	1	2	2	0	0	0	0	*5*
H315	1	0	1	6	19	3	0	0	4	*34*
Sum	*4*	*0*	*7*	*14*	*77*	*7*	*3*	*2*	*7*	***121***

Cyan Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	5	0	0	0	13	0	0	1	2	*21*
H45	0	1	1	1	0	1	0	0	0	*4*
H90	1	0	0	1	7	0	1	1	3	*14*
H135	2	0	0	0	8	0	3	2	7	*22*
H225	1	1	3	5	4	0	1	0	4	*19*
H270	1	0	1	0	2	1	0	0	0	*5*
H315	1	0	4	2	28	0	0	0	1	*36*
Sum	*11*	*2*	*9*	*9*	*62*	*2*	*5*	*4*	*17*	***121***

Blue Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	1	0	0	1	33	2	0	0	5	*42*
H45	0	0	0	0	4	2	0	0	1	*7*
H90	0	0	1	0	15	0	1	0	1	*18*
H135	2	1	1	0	14	1	0	0	0	*19*
H180	0	0	0	1	5	1	4	0	1	*12*
H270	1	1	2	1	0	1	0	0	0	*6*
H315	1	0	0	3	11	2	0	0	0	*17*
Sum	*5*	*2*	*4*	*6*	*82*	*9*	*5*	*0*	*8*	***121***

Purple Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	1	0	0	1	25	1	1	0	2	*31*
H45	0	0	0	1	2	0	0	0	1	*4*
H90	0	0	0	0	19	5	2	0	0	*26*
H135	0	0	2	0	17	2	1	1	2	*25*
H180	0	0	0	0	7	1	3	0	0	*11*
H225	0	0	0	1	3	1	0	0	0	*5*
H315	0	1	0	3	12	0	0	0	3	*19*
Sum	*1*	*1*	*2*	*6*	*85*	*10*	*7*	*1*	*8*	***121***

Magenta Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	3	0	0	0	2	0	0	0	2	*7*
H45	0	0	1	0	1	2	0	0	1	*5*
H90	0	0	1	1	49	4	0	0	1	*56*
H135	1	0	0	3	27	2	0	1	1	*35*
H180	0	0	1	0	6	0	1	0	0	*8*
H225	0	0	1	2	2	0	1	0	0	*6*
H270	1	0	0	0	0	1	1	0	1	*4*
Sum	*5*	*0*	*4*	*6*	*87*	*9*	*3*	*1*	*6*	***121***

APPENDIX E.2- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and Background Effect in Attention.

	Brightness-Saturation									
Back-ground	**B0**	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	**S0**	***Sum***
H0	1	2	7	8	90	10	0	0	3	*121*
H45	5	1	7	11	84	4	3	3	3	*121*
H90	4	1	7	12	77	9	2	2	7	*121*
H135	4	0	7	14	77	7	3	2	7	*121*
H180	11	2	9	9	62	2	5	4	17	*121*
H225	5	2	4	6	82	9	5	0	8	*121*
H270	1	1	2	6	85	10	7	1	8	*121*
H315	5	0	4	6	87	9	3	1	6	*121*
Sum	*36*	*9*	*47*	*72*	*644*	*60*	*28*	*13*	*59*	***968***

APPENDIX E.3- Data Structure (Tabulated Response Distribution) for Hue and Background Effect in Attention.

	Hues										
Back-ground	**H0**	**H45**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
H0		4	8	29	39	25	4	8	1	3	*121*
H45	18		4	9	49	14	4	15	5	3	*121*
H90	20	4		1	34	16	5	30	4	7	*121*
H135	24	1	9		30	12	5	29	4	7	*121*
H180	14	4	10	13		14	4	34	11	17	*121*
H225	36	6	17	17	11		5	16	5	8	*121*
H270	28	3	26	23	11	5		16	1	8	*121*
315	2	4	55	33	8	6	2		5	6	*121*
Sum	*142*	*26*	*129*	*125*	*182*	*92*	*29*	*148*	*36*	*59*	***968***

APPENDIX E.4- Data Structure (Tabulated Response Distribution) for Hue and the First Supplementary Image Sets (scrolling down) in Attention.

Red Background

	Hues									
Images	**H45**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	4	7	26	42	11	0	2	3	5	*100*
2	5	26	16	31	11	1	7	0	3	*100*
3	4	36	13	12	10	4	7	1	13	*100*
4	10	51	4	4	11	4	9	1	6	*100*
5	10	36	7	10	8	4	15	1	9	*100*
6	9	26	13	17	13	3	11	1	7	*100*
7	8	15	10	33	18	4	5	0	7	*100*
Sum	*50*	*197*	*89*	*149*	*82*	*20*	*56*	*7*	*50*	***700***

Yellow Background

	Hues									
Images	**H0**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	8	9	12	48	13	0	5	8	5	*108*
2	25	20	5	38	9	0	5	3	3	*108*
3	26	33	8	18	4	8	3	3	5	*108*
4	42	22	6	8	9	4	7	4	6	*108*
5	33	19	2	20	4	4	17	5	4	*108*
6	27	14	3	22	8	7	15	7	5	*108*
7	13	7	5	47	19	4	3	4	6	*108*
Sum	*174*	*124*	*41*	*201*	*66*	*27*	*55*	*34*	*34*	*756*

Cyan Background

	Hues									
Images	**H0**	**H45**	**H90**	**H135**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	19	0	16	15	13	2	15	3	17	*100*
2	23	5	24	8	9	2	11	4	14	*100*
3	29	9	19	7	0	7	8	6	15	*100*
4	46	7	9	2	7	2	10	5	12	*100*
5	36	1	7	10	9	4	15	5	13	*100*
6	26	6	8	11	9	6	16	6	12	*100*
7	23	2	13	11	16	1	17	4	13	*100*
Sum	*202*	*30*	*96*	*64*	*63*	*24*	*92*	*33*	*96*	*700*

Blue Background

	Hues									
Images	**H0**	**H45**	**H90**	**H135**	**H180**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	34	3	24	24	12	1	6	0	4	*108*
2	40	7	35	6	7	1	5	1	6	*108*
3	61	10	20	2	2	1	4	1	7	*108*
4	63	8	11	1	6	1	11	1	6	*108*
5	49	3	10	11	6	4	17	0	8	*108*
6	46	2	11	1	19	5	16	0	8	*108*
7	44	3	7	6	28	0	13	0	7	*108*
Sum	*337*	*36*	*118*	*51*	*80*	*13*	*72*	*3*	*46*	*756*

APPENDIX E.5- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and the Second Supplementary Image Set (scrolling to the right) in Attention.

Red Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	7	3	5	22	6	2	3	*48*
2	4	4	5	24	4	1	6	*48*
3	8	3	4	17	7	4	5	*48*
4	7	1	1	20	3	2	14	*48*
5	2	3	7	14	3	5	14	*48*
6	4	3	6	12	6	7	10	*48*
7	8	2	4	15	11	2	6	*48*
Sum	*40*	*19*	*32*	*124*	*40*	*23*	*58*	***336***

Yellow Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	5	1	3	29	6	1	3	*48*
2	3	3	9	23	5	0	5	*48*
3	6	4	2	22	5	2	7	*48*
4	6	3	2	22	6	4	5	*48*
5	3	4	4	14	5	5	13	*48*
6	2	4	4	8	13	6	11	*48*
7	3	2	5	12	18	1	7	*48*
Sum	*28*	*21*	*29*	*130*	*58*	*19*	*51*	***336***

Cyan Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	8	2	5	19	3	3	8	*48*
2	5	1	5	20	3	4	10	*48*
3	10	0	6	17	7	2	6	*48*
4	12	3	0	13	9	1	10	*48*
5	5	0	7	12	3	5	16	*48*
6	5	6	4	11	7	6	9	*48*
7	7	2	4	17	7	2	9	*48*
Sum	*52*	*14*	*31*	*109*	*39*	*23*	*68*	***336***

Blue Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	5	1	3	34	2	0	3	*48*
2	1	3	8	19	3	1	13	*48*
3	2	6	4	20	5	3	8	*48*
4	4	2	4	24	2	4	8	*48*
5	4	2	2	16	5	3	16	*48*
6	5	1	7	13	2	6	14	*48*
7	1	2	3	17	9	8	8	*48*
Sum	*22*	*17*	*31*	*143*	*28*	*25*	*70*	***336***

APPENDIX E.6- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and the Third Supplementary Image Set (rotating) in Attention.

Red Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	5	0	5	90	6	2	0	*108*
2	4	3	7	69	18	3	4	*108*
3	7	3	16	58	14	4	6	*108*
4	4	4	9	66	16	2	7	*108*
Sum	*20*	*10*	*37*	*283*	*54*	*11*	*17*	***432***

Yellow Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	7	3	3	82	2	1	2	*100*
2	6	0	6	75	4	2	7	*100*
3	6	2	19	48	13	2	10	*100*
4	5	2	5	68	10	4	6	*100*
Sum	*24*	*7*	*33*	*273*	*29*	*9*	*25*	***400***

Cyan Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	6	0	10	66	9	7	10	*108*
2	8	1	4	69	12	5	9	*108*
3	10	5	17	35	19	3	19	*108*
4	9	2	3	59	15	5	15	*108*
Sum	*33*	*8*	*34*	*229*	*55*	*20*	*53*	***432***

Blue Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	2	2	4	80	4	3	5	*100*
2	4	3	2	80	6	3	2	*100*
3	3	2	13	57	10	4	11	*100*
4	3	4	3	65	15	4	6	*100*
Sum	*12*	*11*	*22*	*282*	*35*	*14*	*24*	***400***

APPENDIX E.7- Data Structure (Tabulated Response Distribution) for Hue and the Third Supplementary Image Set (rotating) in Attention.

Red Background

	Hues							
Images	**H45**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	***Sum***
1	5	20	20	53	10	0	0	*108*
2	3	15	21	53	11	2	3	*108*
3	3	13	22	51	13	3	3	*108*
4	11	12	15	46	18	4	2	*108*
Sum	*22*	*60*	*78*	*203*	*52*	*9*	*8*	***432***

Yellow Background

	Hues							
Images	**H0**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	***Sum***
1	17	4	8	59	5	0	7	*100*
2	12	4	4	57	13	1	9	*100*
3	15	5	7	52	11	2	8	*100*
4	11	8	10	48	11	0	12	*100*
Sum	*55*	*21*	*29*	*216*	*40*	*3*	*36*	***400***

Cyan Background

	Hues							
Images	**H0**	**H45**	**H90**	**H135**	**H225**	**H270**	**H315**	***Sum***
1	17	2	29	15	18	1	26	*108*
2	31	9	16	23	9	2	18	*108*
3	24	9	20	25	10	4	16	*108*
4	26	5	21	20	7	4	25	*108*
Sum	*98*	*25*	*86*	*83*	*44*	*11*	*85*	***432***

Blue Background

	Hues							
Images	**H0**	**H45**	**H90**	**H135**	**H180**	**H270**	**H315**	***Sum***
1	22	3	18	22	20	3	12	*100*
2	48	0	5	12	18	5	12	*100*
3	33	4	11	11	29	2	10	*100*
4	33	4	12	12	22	2	15	*100*
Sum	*136*	*11*	*46*	*57*	*89*	*12*	*49*	***400***

APPENDIX E.8- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and Hue Effect in Preference.

Red Background

	B0	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	**S0**	***Sum***
H45	3	0	0	0	1	2	2	2	0	*10*
H90	1	1	0	1	1	2	0	1	0	*7*
H135	0	0	3	3	7	2	3	2	0	*20*
H180	1	0	2	2	3	2	1	1	1	*13*
H225	2	5	9	7	8	9	1	0	1	*42*
H270	1	2	1	1	0	4	1	0	0	*10*
H315	3	1	2	3	5	2	0	2	1	*19*
Sum	*11*	*9*	*17*	*17*	*25*	*23*	*8*	*8*	*3*	***121***

Yellow Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	1	0	3	3	6	2	3	1	1	*20*
H90	0	2	3	2	1	2	1	1	0	*12*
H135	0	2	5	2	5	2	0	0	0	*16*
H180	1	4	2	2	4	1	1	2	1	*18*
H225	0	2	4	6	8	2	6	0	0	*28*
H270	0	1	0	0	1	1	1	0	1	*5*
H315	1	0	4	5	3	0	4	4	1	*22*
Sum	*3*	*11*	*21*	*20*	*28*	*10*	*16*	*8*	*4*	***121***

Yellow-Green Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	0	0	1	2	14	0	1	0	0	*18*
H45	0	0	1	2	2	3	2	2	0	*12*
H135	0	0	7	5	1	2	2	1	0	*18*
H180	1	0	4	3	2	2	2	3	2	*19*
H225	0	2	6	1	7	2	2	2	1	*23*
H270	1	0	2	1	2	2	5	0	2	*15*
H315	1	0	3	3	4	0	3	1	1	*16*
Sum	*3*	*2*	*24*	*17*	*32*	*11*	*17*	*9*	*6*	***121***

Green Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	0	1	0	2	6	1	0	1	1	*12*
H45	0	0	1	1	3	3	2	1	0	*11*
H90	0	2	4	1	3	2	3	3	0	*18*
H180	0	0	6	5	2	2	0	2	1	*18*
H225	1	0	3	4	10	4	2	1	1	*26*
H270	1	0	2	0	4	3	3	0	0	*13*
H315	2	1	2	2	7	1	3	2	3	*23*
Sum	*4*	*4*	*18*	*15*	*35*	*16*	*13*	*10*	*6*	***121***

Cyan Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	1	0	1	1	1	0	0	0	3	*7*
H45	0	0	0	0	1	0	2	2	4	*9*
H90	0	0	4	1	1	0	0	2	4	*12*
H135	0	0	0	0	0	2	1	3	1	*7*
H225	0	1	5	5	12	7	11	10	2	*53*
H270	0	0	1	2	3	3	3	7	0	*19*
H315	0	0	2	1	3	1	0	5	2	*14*
Sum	*1*	*1*	*13*	*10*	*21*	*13*	*17*	*29*	*16*	***121***

Blue Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	0	1	4	2	12	1	2	3	2	*27*
H45	1	0	0	0	4	2	1	2	0	*10*
H90	0	0	1	1	2	0	1	1	0	*6*
H135	0	0	1	0	5	2	1	0	2	*11*
H180	0	1	3	0	6	4	2	1	1	*18*
H270	0	1	2	5	6	3	4	3	1	*25*
H315	3	0	4	1	5	7	3	0	1	*24*
Sum	*4*	*3*	*15*	*9*	*40*	*19*	*14*	*10*	*7*	***121***

Purple Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	0	1	1	0	3	1	2	0	1	*9*
H45	0	0	2	0	11	1	6	1	0	*21*
H90	0	0	0	0	0	0	0	0	1	*1*
H135	0	0	0	0	3	1	0	3	1	*8*
H180	0	0	3	0	5	3	1	0	1	*13*
H225	0	1	3	3	4	5	8	1	0	*25*
H315	0	0	5	3	8	6	14	7	1	*44*
Sum	*0*	*2*	*14*	*6*	*34*	*17*	*31*	*12*	*5*	***121***

Magenta Background

	B0	B25	B50	B75	BS100	S75	S50	S25	S0	*Sum*
H0	0	0	1	0	3	1	3	2	0	*10*
H45	0	0	0	0	1	1	2	3	2	*9*
H90	0	1	0	0	2	0	1	1	0	*5*
H135	0	0	1	0	2	0	0	2	1	*6*
H180	0	0	2	2	2	3	1	0	1	*11*
H225	0	3	7	8	14	10	8	2	0	*52*
H270	2	0	2	1	3	4	10	3	3	*28*
Sum	*2*	*4*	*13*	*11*	*27*	*19*	*25*	*13*	*7*	***121***

APPENDIX E.9- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and Background Effect in Preference.

	Brightness-Saturation									
Back-Ground	**B0**	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	**S0**	***Sum***
H0	11	9	17	17	25	23	8	8	3	*121*
H45	3	11	21	20	28	10	16	8	4	*121*
H90	3	2	24	17	32	11	17	9	6	*121*
H135	4	4	18	15	35	16	13	10	6	*121*
H180	1	1	13	10	21	13	17	29	16	*121*
H225	4	3	15	9	40	19	14	10	7	*121*
H270	0	2	14	6	34	17	31	12	5	*121*
H315	2	4	13	11	27	19	25	13	7	*121*
Sum	*28*	*36*	*135*	*105*	*242*	*128*	*141*	*99*	*54*	***968***

APPENDIX E.10-Data Structure (Tabulated Response Distribution) for Hue and Background Effect in Preference.

	Hues										
Back-ground	**H0**	**H45**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
H0		7	6	20	11	39	9	15	11	3	*121*
H45	18		12	16	16	28	4	20	3	4	*121*
H90	18	12		18	16	22	12	14	3	6	*121*
H135	11	11	18		17	24	12	18	4	6	*121*
H180	3	5	8	6		51	19	12	1	16	*121*
H225	25	9	6	9	17		24	20	4	7	*121*
H270	8	21	0	7	12	25		43	0	5	*121*
H315	10	7	5	5	10	52	23		2	7	*121*
Sum	*93*	*72*	*55*	*81*	*99*	*241*	*103*	*142*	*28*	*54*	***968***

APPENDIX E.11-Data Structure (Tabulated Response Distribution) for Hue and the First Supplementary Image Sets (scrolling down) in Preference.

Red Background

	Hues									
Images	**H45**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	10	5	11	10	28	11	7	9	9	*100*
2	15	6	7	11	30	11	7	5	8	*100*
3	15	8	10	8	26	9	12	4	8	*100*
4	15	12	7	10	16	14	15	4	7	*100*
5	14	11	4	14	22	17	9	3	6	*100*
6	11	9	10	12	22	19	9	4	4	*100*
7	15	4	7	9	27	18	9	8	3	*100*
Sum	*95*	*55*	*56*	*74*	*171*	*99*	*68*	*37*	*45*	***700***

Yellow Background

	Hues									
Images	**H0**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	15	14	7	14	26	14	9	5	4	*108*
2	17	15	10	13	28	15	6	2	2	*108*
3	18	17	10	11	24	15	8	1	4	*108*
4	18	19	11	8	20	17	9	4	2	*108*
5	23	20	7	9	14	18	8	4	5	*108*
6	17	11	15	13	19	16	13	2	2	*108*
7	20	15	15	9	23	10	12	3	1	*108*
Sum	*128*	*111*	*75*	*77*	*154*	*105*	*65*	*21*	*20*	***756***

Cyan Background

	Hues									
Images	**H0**	**H45**	**H90**	**H135**	**H225**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	9	3	4	8	34	13	11	4	14	*100*
2	13	6	5	6	41	7	9	1	12	*100*
3	17	9	6	9	20	14	15	1	9	*100*
4	11	7	6	1	25	23	16	4	7	*100*
5	10	11	9	9	29	10	14	3	5	*100*
6	13	6	4	9	25	20	13	2	8	*100*
7	7	5	6	8	31	17	14	2	10	*100*
Sum	*80*	*47*	*40*	*50*	*205*	*104*	*92*	*17*	*65*	***700***

Blue Background

	Hues									
Images	**H0**	**H45**	**H90**	**H135**	**H180**	**H270**	**H315**	**B0**	**S0**	***Sum***
1	12	11	4	6	17	29	20	2	7	*108*
2	19	18	4	6	17	21	13	1	9	*108*
3	22	18	8	4	15	18	16	1	6	*108*
4	21	18	13	1	15	20	13	1	6	*108*
5	21	18	8	4	14	23	13	1	6	*108*
6	16	22	7	4	15	18	16	1	9	*108*
7	18	15	5	8	17	26	10	3	6	*108*
Sum	*129*	*120*	*49*	*33*	*110*	*155*	*101*	*10*	*49*	***756***

APPENDIX E.12- Data Structure (Tabulated Response Distribution) for Brightness-Saturation and the Second Supplementary Image Set (scrolling to the right) in Preference.

Red Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	8	7	6	15	3	4	5	*48*
2	8	8	6	16	4	4	2	*48*
3	9	7	3	10	4	8	7	*48*
4	6	4	6	10	10	6	6	*48*
5	5	3	10	15	5	5	5	*48*
6	6	7	6	12	4	5	8	*48*
7	10	2	8	8	6	6	8	*48*
Sum	*52*	*38*	*45*	*86*	*36*	*38*	*41*	***336***

Yellow Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	5	8	5	14	4	9	3	*48*
2	6	9	6	7	8	7	5	*48*
3	8	7	2	11	6	10	4	*48*
4	8	5	6	12	3	6	8	*48*
5	6	8	12	6	3	9	4	*48*
6	3	12	7	9	4	8	5	*48*
7	4	8	9	10	5	8	4	*48*
Sum	*40*	*57*	*47*	*69*	*33*	*57*	*33*	***336***

Cyan Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	5	7	1	11	6	12	6	*48*
2	6	5	5	7	5	10	10	*48*
3	3	5	2	6	10	10	12	*48*
4	4	4	1	13	5	12	9	*48*
5	2	4	11	5	5	9	12	*48*
6	3	8	4	9	8	8	8	*48*
7	6	5	4	8	2	10	13	*48*
Sum	*29*	*38*	*28*	*59*	*41*	*71*	*70*	***336***

Blue Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	3	4	3	21	6	6	5	*48*
2	0	4	6	18	8	6	6	*48*
3	5	2	9	11	9	7	5	*48*
4	6	2	5	15	7	6	7	*48*
5	3	1	5	13	6	9	11	*48*
6	1	7	6	12	2	13	7	*48*
7	4	0	8	17	4	9	6	*48*
Sum	*22*	*20*	*42*	*107*	*42*	*56*	*47*	***336***

APPENDIX E.13-Data Structure (Tabulated Response Distribution) for Brightness-Saturation and the Third Supplementary Image Set (rotating) in Preference.

Red Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	11	17	15	31	11	11	12	*108*
2	15	11	12	25	26	12	7	*108*
3	23	12	22	27	9	5	10	*108*
4	13	14	16	29	17	9	10	*108*
Sum	*62*	*54*	*65*	*112*	*63*	*37*	*39*	***432***

Yellow Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	6	14	18	34	8	9	11	*100*
2	7	23	16	23	12	10	9	*100*
3	13	25	21	14	8	7	12	*100*
4	8	22	22	22	6	10	10	*100*
Sum	*34*	*84*	*77*	*93*	*34*	*36*	*42*	***400***

Cyan Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	4	9	10	28	9	16	32	*108*
2	6	6	14	19	15	22	26	*108*
3	11	13	17	18	8	17	24	*108*
4	6	7	14	23	12	14	32	*108*
Sum	*27*	*35*	*55*	*88*	*44*	*69*	*114*	***432***

Blue Background

	Brightness-Saturation							
Images	**B25**	**B50**	**B75**	**BS100**	**S75**	**S50**	**S25**	***Sum***
1	4	11	9	31	14	19	12	*100*
2	2	5	12	39	13	18	11	*100*
3	9	10	20	26	4	15	16	*100*
4	6	10	13	37	10	13	11	*100*
Sum	*21*	*36*	*54*	*133*	*41*	*65*	*50*	***400***

APPENDIX E.14-Data Structure (Tabulated Response Distribution) for Hue and the Third Supplementary Image Set (rotating) in Preference.

Red Background

	Hues							
Images	**H45**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	***Sum***
1	14	8	12	8	38	14	14	*108*
2	19	14	8	8	29	15	15	*108*
3	20	6	10	20	25	14	13	*108*
4	22	12	11	9	17	17	20	*108*
Sum	*75*	*40*	*41*	*45*	*109*	*60*	*62*	***432***

Yellow Background

	Hues							
Images	**H0**	**H90**	**H135**	**H180**	**H225**	**H270**	**H315**	***Sum***
1	23	19	8	10	19	8	13	*100*
2	27	9	12	14	13	10	15	*100*
3	23	9	13	12	20	7	16	*100*
4	21	10	10	12	18	8	21	*100*
Sum	*94*	*47*	*43*	*48*	*70*	*33*	*65*	***400***

Cyan (180^0) Background

	Hues							
Images	**H0**	**H45**	**H90**	**H135**	**H225**	**H270**	**H315**	***Sum***
1	19	5	7	13	33	13	18	*108*
2	20	12	5	12	27	14	18	*108*
3	13	8	16	15	34	9	13	*108*
4	10	6	10	11	41	17	13	*108*
Sum	*62*	*31*	*38*	*51*	*135*	*53*	*62*	***432***

Blue (225^0) Background

	Hues							
Images	**H0**	**H45**	**H90**	**H135**	**H180**	**H270**	**H315**	***Sum***
1	19	6	8	7	18	20	22	*100*
2	28	8	7	7	13	15	22	*100*
3	25	12	6	9	14	17	17	*100*
4	25	12	8	6	11	18	20	*100*
Sum	*97*	*38*	*29*	*29*	*56*	*70*	*81*	***400***

APPENDIX F

Class, Level, Value Information for ANOVA Procedure.

Classes are columns and rows (block-treatment) of the data set. Levels are the number of groups within each class. Values are the names assigned for each group within that class.

APPENDIX F.1- Analysis Information for Brightness-Saturation and Hue Effect in the Main Image Set.

Red Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H45 H90 H135 H180 H225 H270 H315
Number of observations in data set = 63		

Yellow Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H90 H135 H180 H225 H270 H315
Number of observations in data set = 63		

Yellow-Green Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H135 H180 H225 H270 H315
Number of observations in data set = 63		

Green Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H180 H225 H270 H315
Number of observations in data set = 63		

Cyan Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H225 H270 H315
Number of observations in data set = 63		

Blue Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H180 H270 H315
Number of observations in data set = 63		

Purple Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H180 H225 H315
Number of observations in data set = 63		

Magenta Background

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H180 H225 H270
Number of observations in data set = 63		

APPENDIX F.2- Analysis Information for Brightness-Saturation and Background Effect in the Main Image Set.

Class	Levels	Values
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Background Colors	8	H0 H45 H90 H135 H180 H225 H270 H315
Number of observations in data set = 72		

APPENDIX F.3- Analysis Information for Hue and Background Effect in the Main Image Set.

Class	Levels	Values
Hues	10	B0 H0 H45 H90 H135 H180 H225 H270 H315 S0
Background Colors	8	H0 H45 H90 H135 H180 H225 H270 H315
Number of observations in data set = 72		

APPENDIX F.4- Analysis Information for Hue and the First Supplementary Image Set (scrolling down).

Red Background

Class	Levels	Values
Hues	9	B0 H45 H90 H135 H180 H225 H270 H315 S0
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 63		

Yellow Background

Class	Levels	Values
Hues	9	B0 H0 H90 H135 H180 H225 H270 H315 S0
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 63		

Cyan Background

Class	Levels	Values
Hues	9	B0 H0 H45 H90 H135 H225 H270 H315 S0
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 63		

Blue Background

Class	Levels	Values
Hues	9	B0 H0 H45 H90 H135 H180 H270 H315 S0
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 63		

APPENDIX F.5- Analysis Information for Brightness-Saturation and the Second Supplementary Image Set (scrolling to the right).

Red Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 49		

Yellow Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 49		

Cyan Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 49		

Blue Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	7	1 2 3 4 5 6 7
Number of observations in data set = 49		

APPENDIX F.6- Analysis Information for Brightness-Saturation and the Third Supplementary Image Set (rotating).

Red Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	4	1 2 3 4
Number of observations in data set = 28		

Yellow Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	4	1 2 3 4
Number of observations in data set = 28		

Cyan Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	4	1 2 3 4
Number of observations in data set = 28		

Blue Background

Class	Levels	Values
Brightness-Saturation	7	B25 B50 B75 BS100 S75 S50 S25
Images	4	1 2 3 4
Number of observations in data set = 28		

APPENDIX F.7- Analysis Information for Hue and the Third Supplementary Image Set (rotating).

Red Background

Class	Levels	Values
Hues	7	H45 H90 H135 H180 H225 H270 H315
Images	4	1 2 3 4
Number of observations in data set = 28		

Yellow Background

Class	Levels	Values
Hues	7	H0 H90 H135 H180 H225 H270 H315
Images	4	1 2 3 4
Number of observations in data set = 28		

Cyan Background

Class	Levels	Values
Hues	7	H0 H45 H90 H135 H225 H270 H315
Images	4	1 2 3 4
Number of observations in data set = 28		

Blue Background

Class	Levels	Values
Hues	7	H0 H45 H90 H135 H180 H270 H315
Images	4	1 2 3 4
Number of observations in data set = 28		

APPENDIX F.8- Analysis Information for Gender, Brightness-Saturation and Hue Effect in the Main Image Set.

Red Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H45 H90 H135 H180 H225 H270 H315
Number of observations in data set = 126		

Yellow Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H90 H135 H180 H225 H270 H315
Number of observations in data set = 126		

Yellow-Green Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H135 H180 H225 H270 H315
Number of observations in data set = 126		

Green Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H180 H225 H270 H315
Number of observations in data set = 126		

Cyan Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H225 H270 H315
Number of observations in data set = 126		

Blue Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H180 H270 H315
Number of observations in data set = 126		

Purple Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H180 H225 H315
Number of observations in data set = 126		

Magenta Background

Class	Levels	Values
Gender	2	Male Female
Brightness-Saturation	9	B0 B25 B50 B75 BS100 S75 S50 S25 S0
Hues	7	H0 H45 H90 H135 H180 H225 H270
Number of observations in data set = 126		

APPENDIX G

ANOVA and Duncan's Analysis Information.

DF = Represent the number of terms that are free to vary independently of the other terms in the sum of squares.

Anova SS = It is a sum of squared deviations. It represents variation present in the data.

Mean Square = For each source of variation, it is the sum of squares divided by the degrees of freedom. It yields a measure of the "average" variation.

F-value = The value of the statistic to test H_0. It is calculated by the ratio: Mean Square Group/ Mean Square Error. It tends to be larger if H_a is true.

p-value = The probability that a random variable having the F-distribution is greater than or equal to the calculated value of the F-statistic. A small p-value indicates that the group means are different.

Duncan's Multiple Range Test controls the type I comparison wise error rate, not the experiment wise error rate.

APPENDIX G.1- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and Hue Effect in Attention.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	957.1746	119.6468	7.62	**0.0001**
Hue	6	129.2698	21.5450	1.37	0.2454

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	12.857	BS100
B	1.429	S75
B	1.143	B75
B	1.000	B50
B	0.429	S0
B	0.286	B25
B	0.143	B0
B	0.000	S50
B	0.000	S25

Duncan Grouping	Mean	Hue
A	4.444	H180
A	3.222	H135
A	2.778	H225
A	0.889	H315
A	0.889	H90
A	0.667	H45
A	0.556	H270

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	809.7460	101.2183	5.57	**0.0001**
Hue	6	169.0476	28.1746	1.55	0.1821

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	12.000	BS100
B	1.571	B75
B	1.000	B50
B	0.714	B0
B	0.571	S75
B	0.429	S0
B	0.429	S50
B	0.429	S25
B	0.143	B25

Duncan Grouping	Mean	Hue
A	5.556	H180
A B	2.556	H0
A B	1.778	H315
A B	1.556	H225
A B	1.111	H135
B	0.444	H270
B	0.444	H90

Yellow-Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	664.3175	83.0397	7.23	**0.0001**
Hue	6	140.8254	23.4709	2.04	0.0780

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	11.000	BS100
B	1.714	B75
B	1.286	S75
B	1.000	S0
B	1.000	B50
B	0.571	B0
B	0.286	S50
B	0.286	S25
B	0.143	B25

Duncan Grouping	Mean	Hue
A	4.000	H180
A	3.889	H315
A B	2.556	H0
A B	1.778	H225
A B	0.667	H270
A B	0.444	H45
B	0.111	H135

Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	667.7460	83.4683	7.22	**0.0001**
Hue	6	124.1587	20.6931	1.79	0.1210

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**11.000**	**BS100**
B	2.000	B75
B	1.000	B50
B	1.000	S0
B	1.000	S75
B	0.571	B0
B	0.429	S50
B	0.286	S25
B	0.000	B25

Duncan Grouping	Mean	Hue
A	3.778	H315
A	3.444	H180
A	3.222	H0
A	1.333	H225
A	1.000	H90
A	0.556	H270
A	0.111	H45

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	405.4603	50.6825	4.36	**0.0005**
Hue	6	80.8254	13.4709	1.16	0.3443

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	8.857	BS100
B	2.429	S0
B	1.571	B0
B	1.286	B75
B	1.286	B50
B	0.714	S50
B	0.571	S25
B	0.286	B25
B	0.286	S75

Duncan Grouping	Mean	Hue
A	4.000	H315
A	2.444	H135
A	2.333	H0
A	2.111	H225
A	1.556	H90
A	0.556	H270
A	0.444	H45

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	764.0317	95.5040	6.89	0.0001
Hue	6	97.2698	16.2116	1.17	0.3382

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	11.714	BS100
B	1.286	S75
B	1.143	S0
B	0.857	B75
B	0.714	B0
B	0.714	S50
B	0.571	B50
B	0.286	B25
B	0.000	S25

Duncan Grouping	Mean	Hue
A	4.667	H0
A	2.111	H135
A	2.000	H90
A	1.889	H315
A	1.333	H180
A	0.778	H45
A	0.667	H270

Purple Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	836.3175	104.5397	11.97	**0.0001**
Hue	6	77.0476	12.8413	1.47	0.2085

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**12.143**	**BS100**
B	1.429	S75
B	1.143	S0
B	1.000	S50
B	0.857	B75
B	0.286	B50
B	0.143	S25
B	0.143	B25
B	0.143	B0

Duncan Grouping	Mean	Hue
A	3.444	H0
A	2.889	H90
A	2.778	H135
A	2.111	H315
A	1.222	H180
A	0.556	H225
A	0.444	H45

Magenta Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	878.0317	109.7540	2.84	**0.0116**
Hue	6	273.2698	45.5450	1.18	0.3343

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**12.429**	**BS100**
B	1.286	S75
B	0.857	S0
B	0.857	B75
B	0.714	B0
B	0.571	B50
B	0.429	S50
B	0.143	S25
B	0.000	B25

Duncan Grouping	Mean	Hue
A	6.222	H90
A	3.889	H135
A	0.889	H180
A	0.778	H0
A	0.667	H225
A	0.556	H45
A	0.444	H270

APPENDIX G.2- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and Background Effect in Attention.

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	40928.2778	5116.0347	301.10	**0.0001**
Background Colors	7	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	80.500	BS100
B	9.000	B75
B C	7.500	S75
B C	7.375	S0
B C D	5.875	B50
B C D E	4.500	B0
C D E	3.500	S50
D E	1.625	S25
E	1.125	B25

Duncan Grouping	Mean	Background Colors
A	13.444	H0
A	13.444	H45
A	13.444	H90
A	13.444	H135
A	13.444	H180
A	13.444	H225
A	13.444	H270
A	13.444	H315

APPENDIX G.3- Statistical values obtained from ANOVA Procedure for Hue and Background Effect in Attention.

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	9	4359.9028	484.4336	4.48	0.0002
Background Colors	7	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	26.000	H180
A B	21.143	H315
A B	20.286	H0
A B C	18.429	H90
A B C	17.857	H135
B C D	13.143	H225
C D	7.375	S0
D	4.500	B0
D	4.143	H270
D	3.714	H45

Duncan Grouping	Mean	Background Colors
A	13.444	H0
A	13.444	H45
A	13.444	H90
A	13.444	H135
A	13.444	H180
A	13.444	H225
A	13.444	H270
A	13.444	H315

APPENDIX G.4- Statistical values obtained from ANOVA Procedure for Hue and the First Supplementary Image Set (scrolling down) in Attention.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	4256.5079	532.0635	8.34	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	28.143	H90
A B	21.286	H180
B C	12.714	H135
C D	11.714	H225
C D E	8.000	H315
C D E	7.143	S0
C D E	7.143	H45
D E	2.857	H270
E	1.000	B0

Duncan Grouping	Mean	Images
A	11.111	1
A	11.111	2
A	11.111	3
A	11.111	4
A	11.111	5
A	11.111	6
A	11.111	7

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	4950.2857	618.7857	9.20	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	28.714	H180
A B	24.857	H0
B C	17.714	H90
C D	9.429	H225
D	7.857	H315
D	5.857	H135
D	4.857	B0
D	4.857	S0
D	3.857	H270

Duncan Grouping	Mean	Images
A	12.000	1
A	12.000	2
A	12.000	3
A	12.000	4
A	12.000	5
A	12.000	6
A	12.000	7

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	3412.2222	426.5278	17.00	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	28.857	H0
B	13.714	S0
B	13.714	H90
B	13.143	H315
B C	9.143	H135
B C	9.000	H225
C	4.714	B0
C	4.286	H45
C	3.429	H270

Duncan Grouping	Mean	Images
A	11.111	1
A	11.111	2
A	11.111	3
A	11.111	4
A	11.111	5
A	11.111	6
A	11.111	7

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	11680.5714	1460.0714	28.66	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

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Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**48.143**	**H0**
B	16.857	H90
B C	11.429	H180
B C D	10.286	H315
C D E	7.286	H135
C D E	6.571	S0
C D E	5.143	H45
D E	1.857	H270
E	0.429	B0

Duncan Grouping	Mean	Images
A	12.000	1
A	12.000	2
A	12.000	3
A	12.000	4
A	12.000	5
A	12.000	6
A	12.000	7

APPENDIX G.5- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and the Second Supplementary Image Set (scrolling to the right) in Attention.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	1103.7143	183.9524	17.88	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	17.714	BS100
B	8.286	S25
B C	5.714	S75
B C	5.714	B25
B C	4.571	B75
C	3.286	S50
C	2.714	B50

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	1309.1429	218.1905	12.03	0.0001
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	18.571	BS100
B	8.286	S75
B C	7.286	S25
B C	4.143	B75
B C	4.000	B25
C	3.000	B50
C	2.714	S50

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	898.2857	149.7143	18.48	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	15.571	BS100
B	9.714	S25
B C	7.429	B25
C D	5.571	S75
C D E	4.429	B75
D E	3.286	S50
E	2.000	B50

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	1766.2857	294.3810	18.93	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	20.429	BS100
B	10.000	S25
C	4.429	B75
C	4.000	S75
C	3.571	S50
C	3.143	B25
C	2.429	B50

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

APPENDIX G.6- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and the Third Supplementary Image Set (rotating) in Attention.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	14655.8571	2442.6429	58.08	0.0001
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	70.750	BS100
B	13.500	S75
B C	9.250	B75
B C	5.000	B25
B C	4.250	S25
C	2.750	S50
C	2.500	B50

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	2
A	15.429	3
A	15.429	4

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	13733.2143	2288.8690	44.47	0.0001
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	68.250	BS100
B	8.250	B75
B	7.250	S75
B	6.250	S25
B	6.000	B25
B	2.250	S50
B	1.750	B50

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	8451.9286	1408.6548	25.51	**0.0001**
Images	3	2.6786	0.8929	0.02	0.9971

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**57.250**	**BS100**
B	13.750	S75
B	13.250	S25
B	8.500	B75
B	8.250	B25
B	5.000	S50
B	3.250	B50

Duncan Grouping	Mean	Images
A	16.143	2
A	15.429	1
A	15.429	3
A	15.429	4

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	14853.2143	2475.5357	75.72	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**70.500**	**BS100**
B	8.750	S75
B	6.000	S25
B	5.500	B75
B	3.500	S50
B	3.000	B25
B	2.750	B50

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

APPENDIX G.7- Statistical values obtained from ANOVA Procedure for Hue and the Third Supplementary Image Set (rotating) in Attention.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	6891.3571	1148.5595	105.75	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**50.750**	**H180**
B	19.500	H135
B C	15.000	H90
C	13.000	H225
D	5.500	H45
D	2.250	H270
D	2.000	H315

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	2
A	15.429	3
A	15.429	4

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	7752.7143	1292.1190	129.93	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**54.000**	**H180**
B	13.750	H0
B C	10.000	H225
B C	9.000	H315
C	7.250	H135
C D	5.250	H90
D	0.750	H270

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	1861.8571	310.3095	12.95	**0.0001**
Images	3	0.9643	0.3214	0.01	0.9978

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	24.500	H0
A	21.500	H90
A	21.250	H315
A	20.750	H135
B	11.000	H225
B C	6.250	H45
C	2.000	H270

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	2
A	15.429	3
A	15.000	4

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	2897.7143	482.9524	14.35	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**34.000**	**H0**
B	22.250	H180
B C	14.250	H135
C	12.250	H315
C D	11.500	H90
D	3.000	H270
D	2.750	H45

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

APPENDIX G.8-Statistical values obtained from ANOVA Procedure for Gender Effect on the Main Image Set in Attention.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	0.88	0.3495

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	0.74	0.3914

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Yellow-Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	1.13	0.2901

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	1.05	0.3082

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	0.91	0.3428

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	0.88	0.3509

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Purple Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	1.35	0.2473

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Magenta Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	0.37	0.5417

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

APPENDIX G.9- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and Hue Effect in Preference.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	63.4603	7.9325	2.79	**0.0128**
Hue	6	94.6032	15.7672	5.54	**0.0002**

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	3.5714	BS100
A B	3.2857	S75
A B C	2.4286	B75
A B C	2.4286	B50
A B C	1.5714	B0
B C	1.2857	B25
C	1.1429	S50
C	1.1429	S25
C	0.4286	S0

Duncan Grouping	Mean	Hue
A	4.6667	H225
B	2.2222	H135
B	2.1111	H315
B	1.4444	H180
B	1.1111	H270
B	1.1111	H45
B	0.7778	H90

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	80.6032	10.0754	4.66	**0.0003**
Hue	6	36.1587	6.0265	2.79	**0.0209**

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	4.0000	BS100
A B	3.0000	B50
A B C	2.8571	B75
A B C D	2.2857	S50
B C D E	1.5714	B25
B C D E	1.4286	S75
C D E	1.1429	S25
D E	0.5714	S0
E	0.4286	B0

Duncan Grouping	Mean	Hue
A	3.1111	H225
A B	2.4444	H315
A B	2.2222	H0
A B C	2.0000	H180
A B C	1.7778	H135
B C	1.3333	H90
C	0.5556	H270

Yellow-Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	114.6032	14.3254	3.44	**0.0033**
Hue	6	7.9365	1.3228	0.32	0.9248

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	4.571	BS100
A B	3.429	B50
A B C	2.429	B75
A B C	2.429	S50
B C	1.571	S75
B C	1.286	S25
C	0.857	S0
C	0.429	B0
C	0.286	B25

Duncan Grouping	Mean	Hue
A	2.5556	H225
A	2.1111	H180
A	2.0000	H0
A	2.0000	H135
A	1.7778	H315
A	1.6667	H270
A	1.3333	H45

Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	105.7460	13.2183	5.92	**0.0001**
Hue	6	21.7143	3.6190	1.62	0.1618

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**5.0000**	**BS100**
B	2.5714	B50
B C	2.2857	S75
B C	2.1429	B75
B C	1.8571	S50
B C	1.4286	S25
B C	0.8571	S0
C	0.5714	B25
C	0.5714	B0

Duncan Grouping	Mean	Hue
A	2.8889	H225
A B	2.5556	H315
A B	2.0000	H180
A B	2.0000	H90
A B	1.4444	H270
A B	1.3333	H0
B	1.2222	H45

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	91.4603	11.4325	2.99	**0.0084**
Hue	6	177.4921	29.5820	7.73	**0.0001**

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	4.143	S25
A B	3.000	BS100
A B C	2.429	S50
A B C	2.286	S0
A B C	1.857	S75
A B C	1.857	B50
B C	1.429	B75
C	0.143	B25
C	0.143	B0

Duncan Grouping	Mean	Hue
A	**5.8889**	**H225**
B	2.1111	H270
B	1.5556	H315
B	1.3333	H90
B	1.0000	H45
B	0.7778	H135
B	0.7778	H0

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	144.3175	18.0397	8.04	**0.0001**
Hue	6	46.6032	7.7672	3.46	**0.0064**

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	5.7143	BS100
B	2.7143	S75
B C	2.1429	B50
B C	2.0000	S50
B C	1.4286	S25
B C	1.2857	B75
B C	1.0000	S0
C	0.5714	B0
C	0.4286	B25

Duncan Grouping	Mean	Hue
A	3.0000	H0
A	2.7778	H270
A B	2.6667	H315
A B C	2.0000	H180
B C	1.2222	H135
C	1.1111	H45
C	0.6667	H90

Purple Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	169.1746	21.1468	4.76	**0.0002**
Hue	6	136.1587	22.6931	5.11	**0.0004**

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	4.857	BS100
A B	4.429	S50
B C	2.429	S75
C	2.000	B50
C	1.714	S25
C	0.857	B75
C	0.714	S0
C	0.286	B25
C	0.000	B0

Duncan Grouping	Mean	Hue
A	**4.8889**	**H315**
B	2.7778	H225
B	2.3333	H45
B C	1.4444	H180
B C	1.0000	H0
B C	0.8889	H135
C	0.1111	H90

Magenta Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	88.0317	11.0040	2.58	**0.0200**
Hue	6	195.4921	32.5820	7.63	**0.0001**

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	3.857	BS100
A	3.571	S50
A B	2.714	S75
A B	1.857	B50
A B	1.857	S25
A B	1.571	B75
B	1.000	S0
B	0.571	B25
B	0.286	B0

Duncan Grouping	Mean	Hue
A	**5.7778**	**H225**
B	3.1111	H270
B C	1.2222	H180
B C	1.1111	H0
B C	1.0000	H45
C	0.6667	H135
C	0.5556	H90

APPENDIX G.10- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and Background Effect in Preference.

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	8	4345.2778	543.1597	18.36	**0.0001**
Background Colors	7	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**30.250**	**BS100**
B	17.625	S50
B	16.875	B50
B	16.000	S75
B	13.125	B75
B	12.375	S25
C	6.750	S0
C	4.500	B25
C	3.500	B0

Duncan Grouping	Mean	Background Colors
A	13.444	H0
A	13.444	H45
A	13.444	H90
A	13.444	H135
A	13.444	H180
A	13.444	H225
A	13.444	H270
A	13.444	H315

APPENDIX G.11- Statistical values obtained from ANOVA Procedure for Hue and Background Effect in Preference.

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	9	4887.4206	543.0467	9.43	**0.0001**
Background Colors	7	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**34.429**	**H225**
B	20.286	H315
B C	14.714	H270
B C	14.143	H180
B C	13.286	H0
B C D	11.571	H135
C D	10.286	H45
C D	7.857	H90
C D	6.750	S0
D	3.500	B0

Duncan Grouping	Mean	Background Colors
A	13.444	H0
A	13.444	H45
A	13.444	H90
A	13.444	H135
A	13.444	H180
A	13.444	H225
A	13.444	H270
A	13.444	H315

APPENDIX G.12- Statistical values obtained from ANOVA Procedure for Hue and the First Supplementary Image Set (scrolling down) in Preference.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	1896.7936	237.0992	23.64	0.0001
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	24.429	H225
B	14.143	H270
B	13.571	H45
B C	10.571	H180
C D	9.714	H315
C D E	8.000	H135
C D E	7.857	H90
D E	6.429	S0
E	5.286	B0

Duncan Grouping	Mean	Images
A	11.111	1
A	11.111	2
A	11.111	3
A	11.111	4
A	11.111	5
A	11.111	6
A	11.111	7

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	2366.0000	295.7500	33.01	0.0001
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**22.000**	**H225**
B	18.286	H0
B	15.857	H90
B	15.000	H270
C	11.000	H180
C	10.714	H135
C	9.286	H315
D	3.000	B0
D	2.857	S0

Duncan Grouping	Mean	Images
A	12.000	1
A	12.000	2
A	12.000	3
A	12.000	4
A	12.000	5
A	12.000	6
A	12.000	7

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	3440.5079	430.0635	27.68	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**29.286**	**H225**
B	14.857	H270
B C	13.143	H315
B C D	11.429	H0
C D E	9.286	S0
D E	7.143	H135
E F	6.714	H45
E F	5.714	H90
F	2.429	B0

Duncan Grouping	Mean	Images
A	11.111	1
A	11.111	2
A	11.111	3
A	11.111	4
A	11.111	5
A	11.111	6
A	11.111	7

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	8	2836.2857	354.5357	40.35	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**22.143**	**H270**
B	18.429	H0
B C	17.143	H45
B C	15.714	H180
C	14.429	H315
D	7.000	S0
D	7.000	H90
D	4.714	H135
E	**1.429**	**B0**

Duncan Grouping	Mean	Images
A	12.000	1
A	12.000	2
A	12.000	3
A	12.000	4
A	12.000	5
A	12.000	6
A	12.000	7

APPENDIX G.13- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and the Second Supplementary Image Set (scrolling to the right) in Preference.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	266.0000	44.3333	7.60	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**12.286**	**BS100**
B	7.429	B25
B	6.429	B75
B	5.857	S25
B	5.429	B50
B	5.429	S50
B	5.143	S75

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	159.7143	26.6190	4.78	**0.0011**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	9.857	BS100
A B	8.143	B50
A B	8.143	S50
B C	6.714	B75
B C	5.714	B25
C	4.714	S25
C	4.714	S75

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	292.0000	48.6667	7.36	**0.0001**
Images	6	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	10.143	S50
A	10.000	S25
A B	8.429	BS100
B C	5.857	S75
C	5.429	B50
C	4.143	B25
C	4.000	B75

Duncan Grouping	Mean	Images
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.857	6
A	6.857	7

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	722.4898	120.4150	16.45	**0.0001**
Images	6	0.4898	0.0816	0.01	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**15.286**	**BS100**
B	8.000	S50
B	6.714	S25
B	6.286	B75
B C	6.000	S75
C D	3.143	B25
D	2.857	B50

Duncan Grouping	Mean	Images
A	7.143	6
A	6.857	1
A	6.857	2
A	6.857	3
A	6.857	4
A	6.857	5
A	6.667	7

APPENDIX G.14- Statistical values obtained from ANOVA Procedure for Brightness-Saturation and the Third Supplementary Image Set (rotating) in Preference.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	931.8571	155.3095	7.11	**0.0005**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**28.000**	**BS100**
B	16.250	B75
B	15.750	S75
B	15.500	B25
B	13.500	B50
B	9.750	S25
B	9.250	S50

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	2
A	15.429	3
A	15.429	4

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	1037.2143	172.8690	8.78	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**23.250**	**BS100**
A	**21.000**	**B50**
A	**19.250**	**B75**
B	10.500	S25
B	9.000	S50
B	8.500	B25
B	8.500	S75

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	1511.0000	251.8333	15.03	**0.0001**
Images	3	2.6786	0.8929	0.05	0.9833

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**28.500**	**S25**
B	22.000	BS100
B C	17.250	S50
C D	13.750	B75
C D E	11.000	S75
D E	7.500	B50
E	6.750	B25

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	3
A	15.429	4
A	14.714	2

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Brightness-Saturation	6	1972.7143	328.7857	18.55	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Brightness-Saturation
A	**33.250**	**BS100**
B	16.250	S50
B C	13.500	B75
B C	12.500	S25
B C D	10.250	S75
C D	9.000	B50
D	5.250	B25

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

APPENDIX G.15- Statistical values obtained from ANOVA Procedure for Hue and the Third Supplementary Image Set (rotating) in Preference.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	898.8571	149.8095	5.99	**0.0014**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**27.250**	**H225**
B	18.750	H45
B C	15.500	H315
B C	15.000	H270
B C	11.250	H180
C	10.250	H135
C	10.000	H90

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	2
A	15.429	3
A	15.429	4

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	638.7143	106.4524	10.59	**0.0001**
Images	3	0.0000	0.0000	0.00	1.0000

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**23.500**	**H0**
B	17.500	H225
B C	16.250	H315
C D	12.000	H180
C D	11.750	H90
D	10.750	H135
D	8.250	H270

Duncan Grouping	Mean	Images
A	14.286	1
A	14.286	2
A	14.286	3
A	14.286	4

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	1831.8571	305.3095	17.10	**0.0001**
Images	3	10.7143	3.5714	0.20	0.8950

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	**33.750**	**H225**
B	15.500	H0
B	15.500	H315
B C	12.750	H135
B C	10.750	H270
B C	9.500	H90
C	7.750	H45

Duncan Grouping	Mean	Images
A	15.429	1
A	15.429	2
A	15.429	3
A	14.000	4

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Hue	6	939.7143	156.6190	11.85	**0.0001**
Images	3	5.2500	1.7500	0.13	0.9395

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Hue
A	22.500	H0
A	20.250	H315
A B	17.500	H270
B C	14.000	H180
C D	9.500	H45
D	7.250	H135
D	7.250	H90

Duncan Grouping	Mean	Images
A	14.286	3
A	14.286	2
A	14.286	4
A	13.286	1

APPENDIX G.16- Statistical values obtained from ANOVA Procedure for Gender Effect on the Main Image set in Preference.

Red Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	3.43	0.0667

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Yellow Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	3.60	0.0604

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Yellow-Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	2.14	0.1465

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Green Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	3.51	0.0635

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Cyan Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	2.59	0.1106

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Blue Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	3.38	0.0686

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Purple Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	1.51	0.2215

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

Magenta Background

Source	DF	Anova SS	Mean Square	F-value	p-value
Gender	1	3.5000	3.5000	2.12	0.1482

Duncan's Multiple Range Test:

Means with the same letter are not significantly different.

Duncan Grouping	Mean	Gender
A	1.1270	F
A	0.7937	M

APPENDIX H

GLOSSARY

Achromatic: possessing no hue; being or involving black, gray, or white.

Additive complementary colors: two colors of light, which produce a hueless (white) response, when they are mixed.

Afterimage: visual effect that occurs after light stimulus has been removed.

Afterimage complementary colors: a color and its afterimage complementary hue. A color produces an afterimage of the complementary hue when viewed in daylight with the neutral gray area serving as background.

Assimilation: visual effect, which occurs when two distinctly perceived colors seem to shift in appearance towards each other.

Bezold-Brücke hue shift: visual effect, which occurs when a hue is perceived differently due to the change in the intensity of a spectral light.

Bezold spreading effect: *see* Assimilation.

Border contrast: *see* Edge contrast.

Brightness: attribute of visual sensation according to which an area appears to emit more or less light. It is associated with the total amount of light energy present in a color.

Brightness contrast: *see* Luminance contrast.

Chromatic: having color, or relating to color.

Chromatic contrast: *see* Color contrast.

Color blindness (total): people who suffer from not being able to discriminate any color variations. *See also* Deuteranopia and Protanopia.

Color contrast: relationship between the color of a stimulus and that of its immediate surround.

Color rendering index (CRI): measure of the degree to which the psychophysical colors of objects illuminated by the source conform to those of the same objects illuminated by a reference illuminant for specified conditions.

Color temperature (CT): temperature (in Kelvin, K) to which a blackbody radiator must be raised to match the color of a light source.

Deuteranopia: people who suffer from perceiving the part of the spectrum as gray, which appears to the normal vision as green.

Edge contrast: visual effect which occurs when two juxtaposed areas of uniform colors having the same hue, but slightly different luminance factor are viewed. Adjacent to the boundary between the two areas an appearance of a relative enhancement of lightness of the lighter area, and a corresponding darkening of the adjoining darker area occurs.

Fixation: to focus or concentrate one's gaze or attention intently on someplace for a while.

Helson-Judd effect: visual effect which occurs when a surface lighter than the surroundings takes on the cast of the hue of the illuminant, and a surface darker than the surroundings takes on the cast of the hue of the afterimage complementary of the illuminant's hue.

Hue: an attribute of color usually associated with its name such as red, blue, yellow, etc.

Incident light: light that falls onto a surface or object.

JPEG: (the Joint Photographic Experts Group), a format commonly used to display photographs and other continuous-tone images.

Lightness: refers to the apparent relative reflectance or transmittance of a stimulus regardless of its physical nature.

Luminance: objectively measured light reflected from or transmitted through objects.

Luminance contrast: relative luminance difference of two areas within a visual field.

Mach contrast/ Mach-band effect: *see* Edge contrast.

Metamers: a set of stimuli all of which have a different wavelength composition that can evoke the same color sensation.

Munsell color system: system for ordering surface colors by specifying hue, chroma (saturation), and value (brightness or lightness).

Nonspectral hues: hues that are not present in the sun's spectrum or in the spectrum of any source. Purple, purplish red, and a range of neighboring red hues are nonspectral hues.

Protanopia: people who suffer from perceiving the part of the spectrum as gray, which appears to the normal vision as blue-green and red.

Reflectance: percentage of incident light that is radiated from a surface.

Reversed contrast: *see* Assimilation.

RGB model: (Red, Green, Blue model), a model based on the representation of the visible spectrum by mixing three basic components of colored light in various proportions and intensities. These components are known as colors of red, green, and blue.

Saccade: a small rapid movement of the eye especially as it jumps from fixation on one point to another (as in reading).

Saturation: attribute of color that refers to relative purity. When a pure, vivid, strong shade of a hue is mixed with any amount of gray, weaker or paler colors from that hue are produced.

Simultaneous contrast: visual effect which occurs when two different color patches of equal size are placed side by side, where both will exhibit changes of appearance.

Spatial contrast: *see* Simultaneous contrast.

Spectral hues: hues represented by monochromatic radiation from 380 to 780 nm. They are present in the sun's visible spectrum, a common example of which is provided by a rainbow.

Spectral power distribution: description of the spectral character of a radiation by the relative spectral distribution of some radiometric quantity.

Stimulus: an agent (as an environmental change) that directly influences the activity of a living organism or one of its parts (as by exciting a sensory organ).

Successive contrast: visual effect which occurs when eyes are fixed on a colored patch for a sufficient period of time, and then moved on to another patch of a different color. It is likely that the image of the first patch will be perceived upon the image of the second. *See also* Afterimage.

Transmittance: ratio of the transmitted light to the incident light.