THE EFFECTS OF COLORS IN A WORK ENVIRONMENT: A CASE STUDY IN ÇANKAYA UNIVERSITY LIBRARY

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Title of the Thesis: **The Effects of Colors in a Work Environment: A Case Study in Çankaya University Library.**

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ABSTRACT

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The interior environment has proven the impacts on the occupants' behaviour and health status. Moreover, color has different psychological and physiological effects on humans that are researched and confirmed through the different studies in the literature. In this research the impact of color in a work environment is investigated. Firstly, the literature review is performed, where different results had been found for the different colors; red, blue (chromatic), black and white (achromatic). The studies suggest several effects of colours on the human body and mind through several levels of impact. Through the case study of this research, four colors based on the NCS color system are chosen for their frequent use in the research and contrast to each other; white, black, red and blue. Through a performance test designed to simulate a work environment, fifty participants have taken two sets of questions. The performance of the participants is assessed based on productivity (completion time) and accuracy (number of correct answers). By applying one-way ANOVA and t-test analyses on the full set of the results, significant difference at the $p<0.05$ level have been found between the four colors based on productivity and accuracy. Moreover, white and black colors have been found more suitable for office areas, where productivity is required, while red and blue can be used in workshop and meeting areas to simulate activeness and intensity.

Keywords: effect of color, work environment, productivity, accuracy, NCS color system

ÖZ

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İç mekanın kullanıcıların davranışları ve sağlık durumu üzerinde etkili olduğu kanıtlanmıştır. Üstelik, renk, insanlar üzerinde farklı psikolojik ve fizyolojik etkilere sahiptir ve bunlar, literatürdeki farklı çalışmalar yoluyla araştırılmış ve teyit edilmiştir. Bu araştırmada renklerin çalışma ortamındaki etkisi araştırılmıştır. İlk olarak, farklı renkler için; bunlar, kırmızı, mavi, siyah ve beyaz, farklı sonuçların bulunduğu literatür taraması gerçekleştirilmiştir. Araştırmalar, renklerin insan vücudu ve zihin üzerindeki etkilerini çeşitli etki seviyeleriyle ortaya koymaktadır. Bu araştırmanın vaka çalışması boyunca, araştırmalarda sıkça kullanılan ve birbirlerine zıt oldukları için NCS renk sistemine dayalı dört renk seçilmiştir; beyaz, siyah, kırmızı ve mavi. Bir çalışma ortamını simule etmek için tasarlanmış bir performans testi ile, elli katılımcı iki soru seti almıştır. Katılımcıların performansı, verimlilik (tamamlama süresi) ve doğruluk (doğru cevapların sayısı) temel alınarak değerlendirilmiştir. Tek yönlü ANOVA ve t test analiz yöntemleri tüm renk verilerine uygulanmış, üretkenlik ve doğruluk temel alınarak dört renk arasında $p < 0.05$ düzeyinde anlamlı farklılık bulunmuştur. Üstelik verimlilik gerektiren ofis alanları için beyaz ve siyah renkler daha uygun bulunmuş; atölye ve toplantı alanlarında aktiflik ve çarpıcılığı canlandırmak için kırmızı ya da mavi renklerin kullanılabileceği bulunmuştur.

Anahtar Kelimeler: rengin etkisi, çalışma alanı, üretkenlik, doğruluk, NCS renk sistemi

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CHAPTER 1

INTRODUCTION

1.1 Subject Overview

The impact of color on human performance is a research subject that has been studied for a long time in several contexts. However, for the past two decades a new direction towards understanding the effects on the employees in work environment emerged from the understanding that the conventional white interiors that mostly dominated the interiors of the work environments could be improved to increase productivity and the overall mood of the space users (Office Principles, 2014). This chapter, provides an overview about the research subject, as well as identifying the aim, problem statement, and the structure and methodology of the thesis.

Enhancing the interior work environment is the goal of many companies who realized that there are several factors that affect the business in their offices beside talent and office supplies. Therefore, researches show that improving the interior design of the administrative work environment could assist worker to accomplish the tasks quicker and efficiently, maximize the resources' use, ease work management, enhance communication within the staff, increase the comfort of the users, and increase positivity and soothing effects in the busy environment (Kamarulzaman et al., 2011).

Moreover, there are several studies that examined the influence of different factors on the preference, performance, and emotions of the people in different contexts (Akcay and Sun, 2010; Bakker et al., 2015; Elliot et al., 2007; Kwallek, Lewis, and Robbins, 1997). Therefore, it became important to understand these impacts in order to develop the interior design based on proven studies. Nonetheless, none of these studies have reached a complete consensus on how the color affects humans as a sole factor, although there are few that tried to study the correlation between color correlation with age, gender and educational level in work environments using other factors such as light (Poursafar, Devi, and Rodrigues, 2016).

This study focuses on using a standardized color system into designing the interior of a work environment and studying the color effect on performance and accuracy of task performance and find any significant differences between the different colors. The research ensures a sufficient review through the literature for the results and conclusions of previous experiments and studies, as well as studying the influence of the factors included in this study.

1.2 Aim of the Study

The main aim of this research is to study the effect of interior design color in the work environment on individuals and correlate the task performance and accuracy to the interior color of the work space cubicles using an experimental methodology. Therefore, the main objectives of this study are as follows:

1. Understand the correlation between color and human performance in work environment context.
2. Study the difference between four common colors (chromatic: red and blue; and achromatic: white and black) in terms of performance and accuracy in tasks that are expected in the work environment.
3. Recommend the colors that are most suitable for the different areas of the work environment according to the task performed in each area.

1.3 Problem Statement

Despite the many trails to understand the effect of color on humans in terms of task performance, there are several gaps within the literature that has not been addressed yet. Therefore, the significance of this study emerges from the following:

1. Using NCS color system in evaluating performance of individuals, as a stimuli and a tool.
2. Adopting the work environment, which is one of the least environments researched for color impacts.
3. Adding additional support for impacts of color on human performance in order to work towards a consensus on the effects of different colors with different achromatic and chromatic colors.

The research adopts an objective methodology through readings from an experimental procedure. An objective methodology is a scientific research method, which does not involve feelings, opinions or perspectives (Cowart, 1997; Kothari, 2004).

1.4 Thesis Structure

In order to achieve the main objective of this research of studying the effects of color in the interior design of the work environment, the structure of the thesis and its methodology has been designed for that purpose. Therefore, the thesis starts by providing an overview on the subject, the aim and objectives of the study, and the gap within the previous studies, which gives the research its significance. The second chapter provides a sufficient review of the literature on the subjects of color and its standards, the effect of color on psychology and performance, the correlation of color in the work environment with individual, the color relation with space perception, and the color use in the working environment.

The third chapter reviews the methodology of the research by introducing the questions and the hypotheses that are tested in the case study. Moreover, the study design is provided using a work environment setup and NCS color system, along with the objective methodology design, i.e. performance test, and the sample and analysis of the case study. The fourth chapter shows the results of the case study in a descriptive form, then an analysis and discussion are performed in order to establish the statistical testing required for the study results. Finally, the conclusion chapter provides hypotheses testing based on the analysis and provides the researcher's recommendations for work environments, designers and future research.

CHAPTER 2

COLOR AND WORK ENVIRONMENT

This chapter performs a review through the literature to the concept of color and its effects and applications in the work environments. Therefore, many topics are examined including; color theory and standards, color psychology and preferences, and the application of color in work environments. Moreover, results from previous studies are reviewed in order to understand the general impact of color on performance and productivity. The knowledge compiled in this part of the research is essential to build the basic elements of the present study such as hypotheses and modeled designs.

2.1 Color: A Definition

Newton is one of the first scientist to explain the relationship between color and light in the seventeenth century, as he proved that white light consists of seven colors as shown in Figure 2.1, which could be seen using prism or through the rainbow phenomenon (Bleicher, 2012). Newton also explained the relationship between color and light, where the color seen by the human eye is a reflection of that color from the light source into the eye, while the object absorbs the spectrum of the other colors (Mollica, 2013), as shown in Figure 2.2.

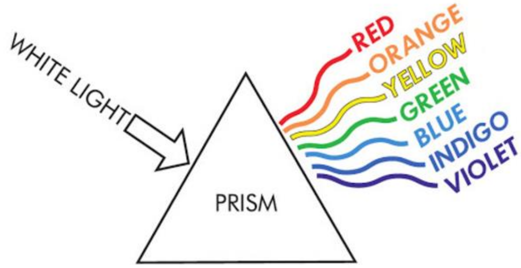

Figure 2.1: White color broken into seven colors through a prism (Bleicher, 2012, p. 6)

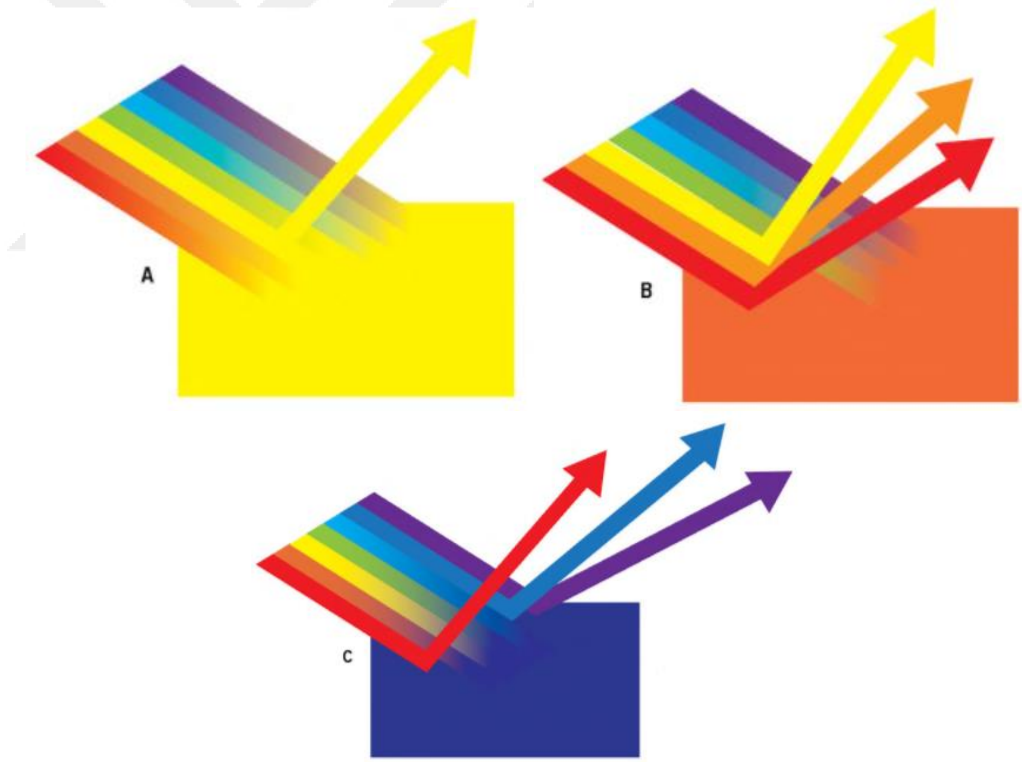

Figure 2.2: Lighting and reflection according to object/ surface color (Mollica, 2013, p.9) make the figures smaller, they are too big.

A) If the object color is yellow, all colors are absorbed by the object, except for the yellow that get reflected.
B) If the object color is orange, all colors are absorbed by the object, except for the yellow, orange and red that gets reflected.
C) If the object color is purple, all colors are absorbed by the object, except for the red, blue and violet that gets reflected.

Nonetheless, a deep understanding of color and its theory is required in order to be able to design the models planned in this research efficiently. Therefore, the basic color theory, Munsell order system and other color standards are reviewed in the following sections in order to build a standardized set of colors to be used in the study.

2.1.1 Color Theory

In order to be able to study color, the subject need to be standardized through a certain concept. Therefore, the color theory is set of guidance for colors based on their mixtures and visual impacts (Smith, Wright, and Horton, 1999). A certain color is called a hue and there are three parameters that determines the color properties, which are (Agoston, 1979):

1. Intensity: it represents the brightness of the color, which could be altered by adding white or black to the hue.
2. Saturation: the clearness of the color which makes it appear pure or pale.
3. Value: measured by the amount of light that is reflected from a certain hue, which translates to the illuminance measurement.

These parameters are connected to each other to determine the quality of a hue. If black is added to a hue, it is called a shade, while adding white makes it a tint. Another way to classify colors is according to their types. There are three primary colors, which are red, yellow and blue. Moreover, mixing two primary colors results into secondary colors.

Mixing red with yellow produces the orange color, mixing yellow with blue produces green, and mixing red with blue produces purple. The last classification is called tertiary colors, where a primary color is mixed with a secondary color (van Hagen, 2003). The basic colors classification is compiled through a two-dimensional tool that is called the Itten's twelve color wheel as shown in Figure 2.3. Colors that are adjacent to each other on the wheel are called analogous, while colors that are directly opposite to each other are called complementary or contrasting colors.

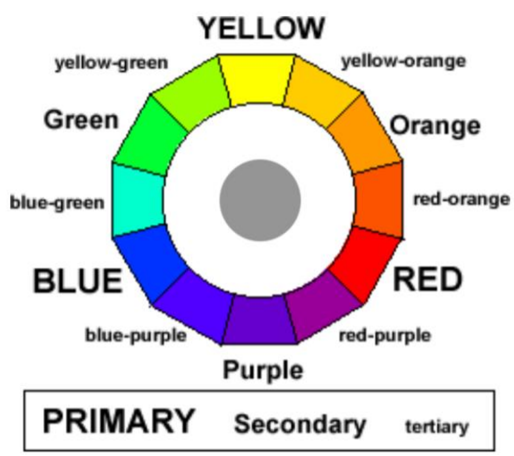

Figure 2.3: Itten's twelve hue color wheel (Zelanski & Pat Fisher, 2012. P. 14)

2.1.2 Color Order Systems

There are continuous trials to establish a standardized color system in order for designers and industrial professionals to be able to communicate color based on certain specifications. The first recorded attempt towards this goal was by Aristotle around 350 BC, while other trials continued by scientists and specialized institutions such as the Swedish Standards Institution and Optical Society of America (Nemcsics and Caivano, 2015). The Munsell color order system was established by Dr. Albert Henry Munsell in order to ease the communication of color and make it more accurate (Munsell Color, 2012). The Munsell color system is used in all industries that are concerned with color specifications; from design, paint, ink, reaching to fabric. The first specification of Munsell color system was published by him in 1915 after ten years of work on refining the structure of the specification. The strength of Munsell order system emerges from the long research made by the inventor to the previous attempts to create standards for colors, which resulted into a system that describes color through three main variables (Cochrane, 2014):

1. Hue: which is the color name that is assigned to an alphabetical symbol.
2. Value: which describes the darkness degree of the color through a numerical value.
3. Chroma: which describes the purity and vividness of the color through a numerical value.

Another advantage of using the Munsell color system is that the parameters that describe the color is built on scientific laws, such as Weber-Fechner law of sensation. Moreover, Munsell have used the concept of Maxwell disk to build the three-dimensional diagram that specifies each color based on the three parameters (Cochrane, 2014); hue, value and chroma, as shown in Figure 2.4.

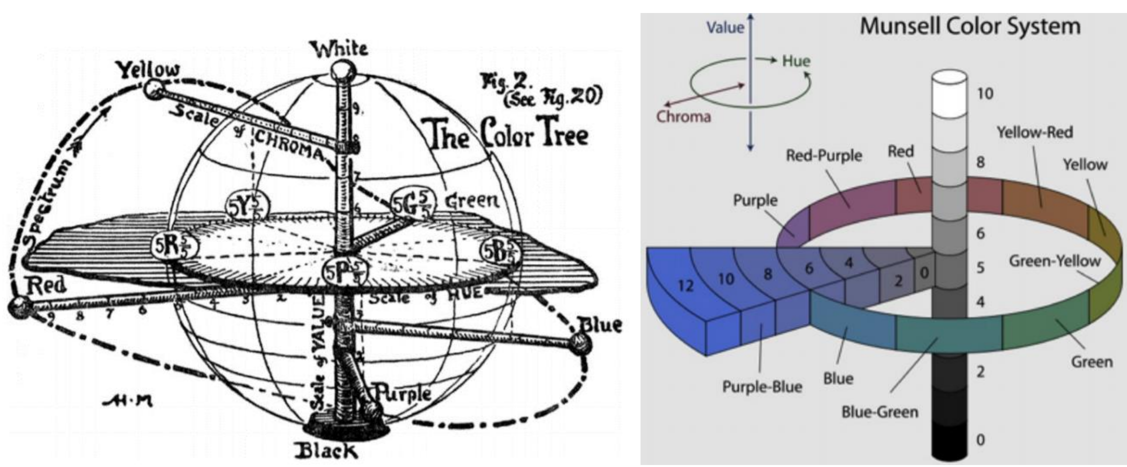

Figure 2.4: Munsell color system. The color tree developed by Munsell (left) and a schematic diagram of the system (right) (Cochrane, 2014, pp. 28-29)

The simplified way in communicating color using the Munsell order system is through the color circle shown in Figure 2.5. The circle shows ten hues that are used as a reference at a neutral value and the maximum chroma. The colors in Munsell system is represented by a (Hue, Value and Chroma) notation (Nemcsics and Caivano, 2015). For example, a color can that is noted as 5R 7/8 would mean that the hue is 5R (red), value is seven and chroma is eight.

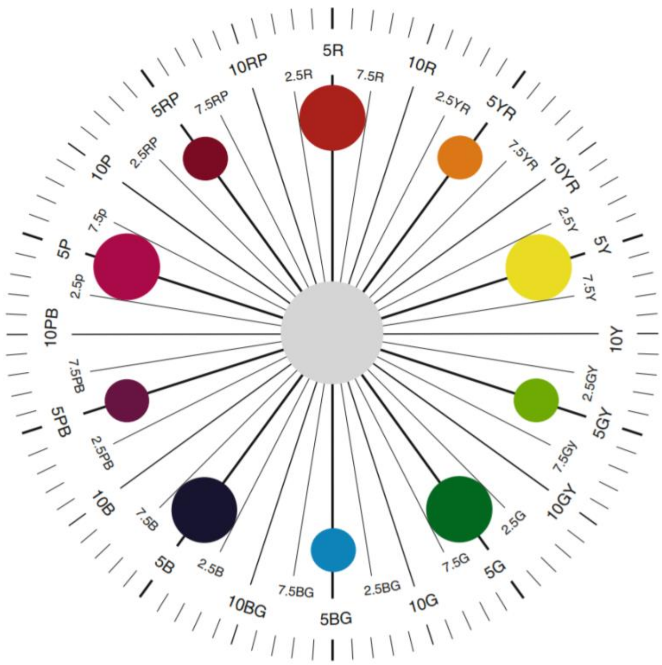

Figure 2.5: Munsell system color circle (Nemcsics and Caivano, 2015, p. 5)

The color system used in this research is the NCS system, which is defined as a psychometric model that describes colors as an application of Hering's theory. The main advantage of the NCS color system is that it describes colors based on their perception, is based on the relations of colors with each other, and references colors based on their all possible properties (Hard and Sivik, 1981). The Hering's theory of natural color system defines color based on resemblance to each other. Therefore, the system was further developed by adding the color properties to it including hue, saturation and lightness, which made the system usable (Hard, Sivik, and Tonnquist, NCS, 1996).

The NCS sets six elementary colors, which are white, black, yellow, red, blue and green, as shown in Figure 2.6. Moreover, the NCS system relates the colors in a three-dimensional model called the NCS color space, where a section in it would give a triangle that provides certain degrees between three colors, as shown in Figure 2.7. The color references start by giving the standard color, degree of blackness, degree of chromatins, and hues' numbers. As shown in Figure 2.8. Cool colors are blue, green and light purple, while warm colors are red, yellow and orange (Hard and Sivik, 1981).

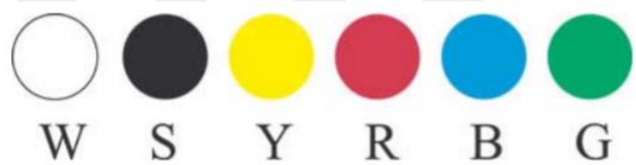

Figure 2.6: NCS Elementary colors (Hard and Sivik, 1981, p. 133)

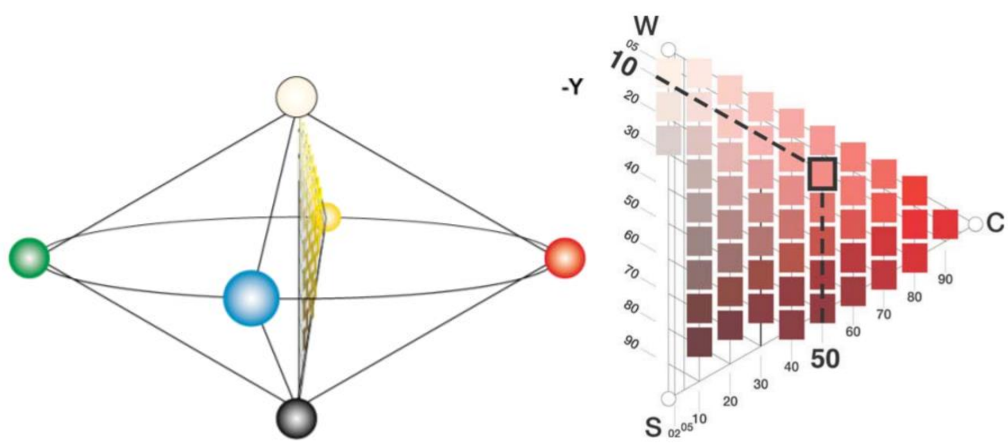

Figure 2.7: NCS color space (Hard, Sivik, and Tonnquist, 1996, p. 182)

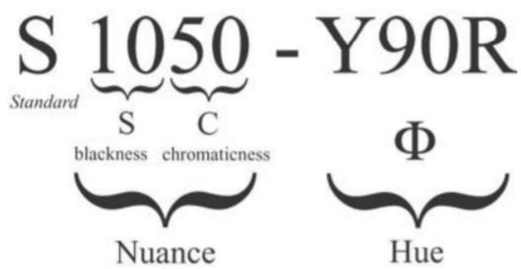

Figure 2.8: NCS color notation/ referencing (Hard, Sivik, and Tonnquist, 1996, p. 184)

2.2 Psychological Aspects of Color and Preferences

Space perception is an important concept that describes the way an individual creates an image in his brain of a certain environment, which is of a visual nature. Through space perception the person is able to make sense of the locations, sizes and distances of objects in a three-dimensional manner. Therefore, the way a person perceives those parameter does not necessarily reflect the reality (Atli, 2010). Franz (2006) states that there are several elements that is delivered visually including dimension and color, which they are perceived together and subsequently affect each other. In architecture, there are general rules that explain the relationship between color perception and space perception, where light colors increase the spaciousness of a space and dark saturated colors reduce it.

The properties of the color effectively impact the space perception. For instances, using hues such as red would make distances seem shorter, while a blue color would make the human eye perceive the distance as longer. Moreover, increasing the brightness of the color is proven to make distances shorter, while decreasing it have an opposite effect. Thus, the colors can be ordered in terms of this effect from the furthering to nearing effect as black, blue, green, yellow, white and red. Nonetheless, the brightness of a color in a space is affected by the adjacent colors in the space, where this property shall be studied in conjunction with them (Atli, 2010).

In evaluating color and space perception, Franz (2006) have used four main dimensions and eight categories under them for evaluation. Moreover, under each category a set of pair adjectives have been used to describe each of them, as shown in Table 2.1. The study used sixty-four model shots with different dimensions and colors in order to understand the impact of color on the space perception. The author studied the results of the models separately and collectively, where it was confirmed that lighter colors have increased the spaciousness effect of the space and the darker colors worked the other way. Furthermore, the perception of the light properties differs with other interior elements such as lighting and reflection. Therefore, the brightness and chroma of the color would change with the light intensity and type, and subsequently affects the space perception (Brainard & Maloney, 2011).

Table 2.1: Color and space assessment dimensions, categories and adjective (Franz, 2006, p. 4)

Dimension	**Category**	**Low Adjective**	**High Adjective**
Valence	Pleasantness	Unpleasant	Pleasant
	Beauty	Ugly	Beautiful
Arousal	Excitement	Calming	Exciting
	Interest	Interesting	Boring
Dominance	Obstructiveness	Helpful	Obstructive
	Gravity	Light	Oppressive
Spatiality	Spaciousness	Narrow	Spacious
	Enclosure	Open	Enclosed

There are health studies that have proven the effect of color in the physiology and psychology of the humans. Studies at Cornell University have shown that the biological clock of a person can be reset by applying blue light to the knees from the backside

(Bleicher, 2012). Another study in Italy has used fully painted rooms with green and red to record the body responses of the participants. The green color had caused the blood vessels to dilate, while the participants have experienced muscle toning in the red room. One of the most interesting findings of this study is that the sighted and blind participant responded exactly the same to both colors, which made the researcher conclude that human may have color receptors in their bodies beyond the sight (Bleicher, 2012).

Studying the psychology of color have taken several forms in the literature between different context settings and assessment methods. In a review performed by Jalil, Yunus, and Said (2012), forty study results have been used in order to conclude the psychological effect of color on participants. The gap in the literature has been identified as using limited colors including red, blue and white. The results of the studies show the following psychological impacts on the participants (Jalil, Yunus, and Said, 2012):

1. White has a positive impact on wellbeing and performance. However, the results were in consistent as the response depended on the mental alertness of the participant. The white color generally was described as natural and accepted.
2. Red simulated excitement in most of the studies, as well as drawing attention to important tasks. However, other negative behaviors were also simulated including avoidance and waring during task performing.
3. Blue had also simulated excitement in other studies with a positive impact on performance. Nonetheless, similar to gray and beige, blue had a negative effect on attention to details and concentration on goals in some studies, in addition to drowsy effects.
4. Beige simulated less movement density and low concentration.
5. Green was found to have a calming and a stress reduction effect.

Furthermore, the emergence of color reaction is believed to be from several levels of interaction between the color and the individual. Talaei (2013) states that the basic human reaction to color is of a biological effect, which is mainly related to the environment and the nature of the human body. The second level of reaction occurs in the subconscious of the individuals based on their experiences and mental pictures of the color. The next level is mainly influenced by the symbolism of the color to the individuals based on beliefs. The last three levels are related to the cultural background of the individuals, social engagement, and individual interest. The levels of reaction to color is illustrated in the pyramid in Figure 2.9. A survey of associated emotions from the literature was performed by Schaie (1966), where Table 2.2 shows a summary of the study findings.

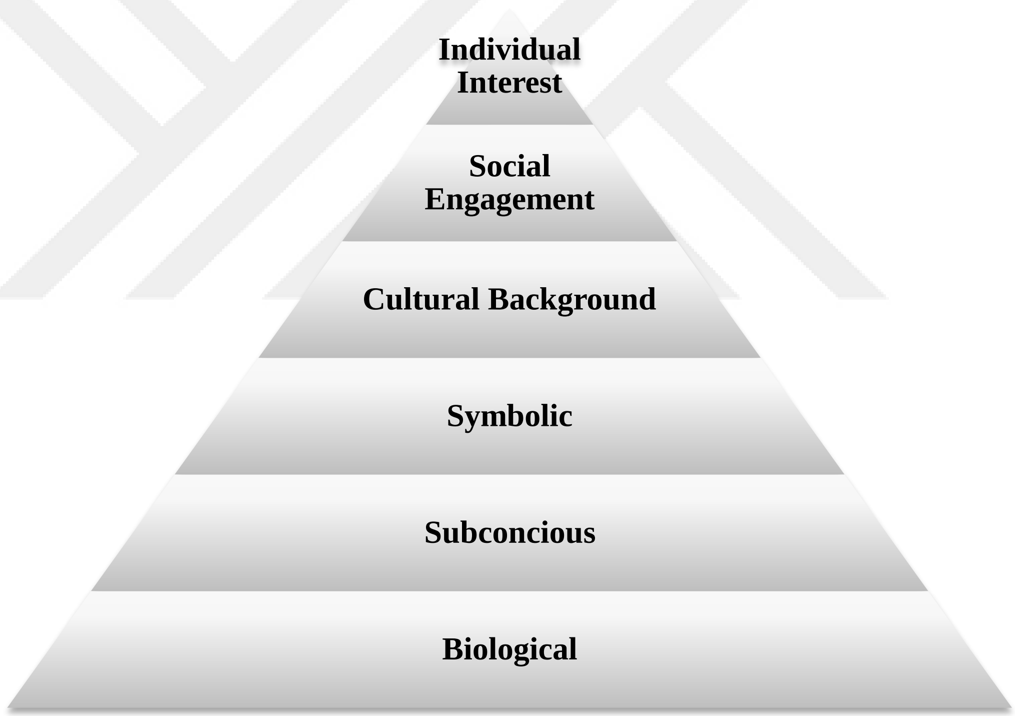

Figure 2.9: Levels of human reaction to color (Talaei, 2013, p. 22)

Table 2.2: Emotions and meaning of colors as compiled from the literature (Schaie, 1966, pp. 519-520)

Color	**Emotions and Meanings**
Red	Happiness, hot, excitement, aggression, explosive, active, intensity, hostile, powerful, strong, protective
Orange	Hot, unpleasant, excitement, tempered, warm, delightful, upset, happy
Yellow	Very unpleasant, peaceful, cheerful, envy, hostile, aggressive, joyful, excitement
Green	Enjoyment, emotion control, emotional, young, secure, comfortable, calm, peaceful, fresh
Blue	Dignity, sad, tender, cool, control, social, secure, comfortable, ability, soothing, strong, deep
Purple	Depressing, energetic, ability, sad, optimistic
Black	Sad, intense, anxious, fear, depression, strong, old, upset, contrast, powerful, unhappy
White	Pure, tender, soothing, empty
Brown	Sad, disagree, ability, secure, comfortable

When speaking of preferences for color, the main subject in question is always the factors that affect it. In a study that involved seventy-two participants, three age groups were exposed to six colors; blue, red, yellow, green, white and black, with mean ages as seven, eleven and thirty. The results of the study, as shown in Figure 2.10, indicate that all groups had their highest preference for the blue color, while the lowest age group had the second highest preference as yellow. Moreover, the second age group and adults have had the second preference for red (Terwogt and Hoeksma, 1995).

The personality traits of the individuals also affected their choice of colors in an earlier study. By comparing the consistency of color choice and the range of color chosen, participants' personalities were classified as mature, emotionally retarded, creative, or have a normal behavior (Schaie, 1966). Furthermore, culture has been found as an influential factor in color preference (Jalil, Yunus, and Said, 2012).

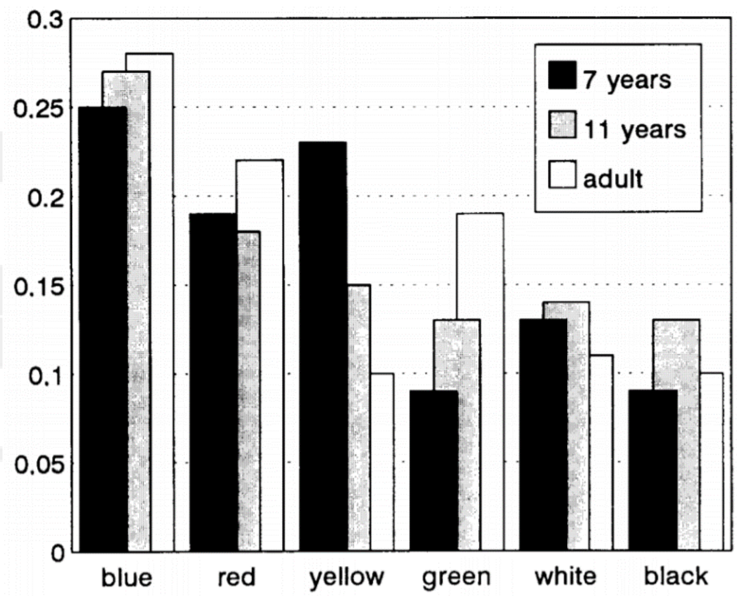

Figure 2.10: Preference of color based on age in Terwogt and Hoeksma (1995, p.11) study

Moreover, this research is focusing on two demographic factors in color preference, which are gender and level of education. Therefore, the next sections are focusing on the studies performed in the literature in order to set the base for comparison and discussion for the present case study.

Through the review of the literature, the gender factor is one of the affecting factor when it comes to the preference in color. For instance, in a marketing study involving 608 participants from different countries, women were found to pay more attention to color that men in day to day activities such as choosing a product (Akcay and Sun, 2010). Moreover, a study investigating the impact of gender and parenting on the choice of preferred colors showed that males mainly tend to choose blue color then green, while women have chosen purple then blue, on a total sample size of 2,103 (Cohen, 2013).

Furthermore, an American study reviewed several sources from the literature, where different color preferences according to gender were found. One of the reviewed studies stated that there was no significant difference between genders based on their color preference. However, this study involved 5,590 participants and was mainly focused on color preference, using eleven non-standardized colors, based on gender and sexual orientation, while no specific space context was adopted. The results show that 45% of the males preferred blue color, followed by green (19.1%), and red and black with 12.1% for each. Nonetheless, women results have shown that they preferred green with 27.9%, followed by blue (24.9%), and purple (12.2%). Another result of the study is that homosexual participants did not show different results in both cases (Ellis and Ficek, 2001).

Another study has used Munsell order system colors, in addition to white, brown, grey and black, in a preference research that correlated the results of 1,077 participants to architectural contexts and gender. The preferences percentages comparison between males and females for offices and meeting rooms are shown in Figure 2.11. However, while white is the first chosen color for both genders and both cases, it was found influential in choosing color for the office but not the meeting rooms (Bakker et al., 2015).

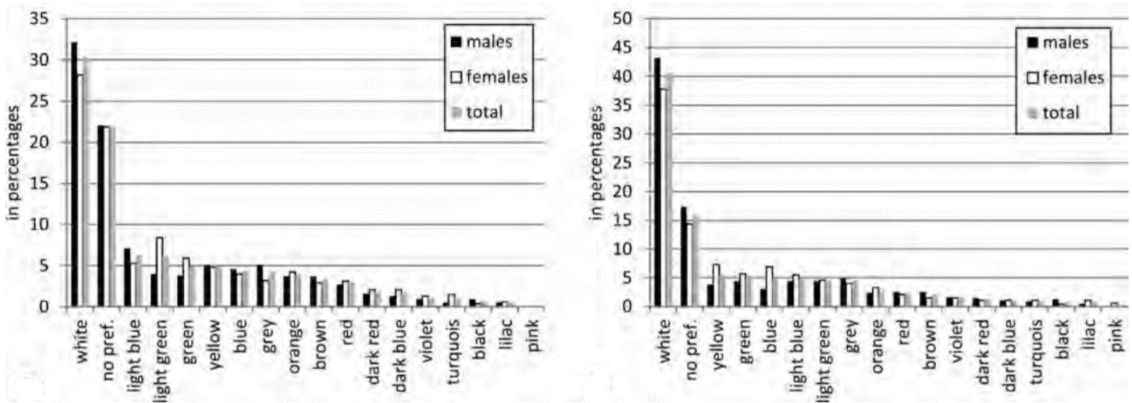

Figure 2.11: Genders color preference for meeting rooms (left) and offices (right) (Bakker et al., 2015, p.65)

Moreover, a study that used Munsell order system without a certain context have studied the gender and cultural difference, Arabic and English, in choosing the preferred color. Results show that genders from both cultural groups have significant differences in their preferred color choice. While males from both cultural backgrounds have chosen colors ranging between the blue and green hues, Arabic females have preferred red and pink colors and English females have preferred purple and blue colors (Al-Rasheed, 2015). Results are shown through the graphs in Figure 2.12.

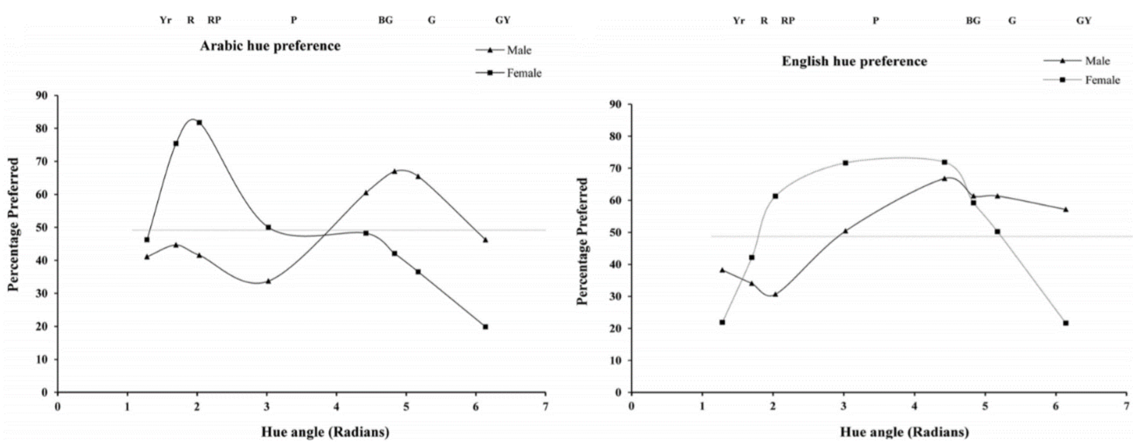

Figure 2.12: Gender color preference through cultural difference (Arabic on the left and English on the right) (Al-Rasheed, 2015, p. 3)

On the contrary to gender, there are fewer studies that correlated the education level factor with the color preference. The previously reviewed study of Bakker et al. (2015) have indicated that the level of education is influential in color preference; however, the factor was found effective in the preference of color in the meeting room but not offices. Nonetheless, a study involving eighty students at different higher education levels and backgrounds had different preferences for clothing and living room colors. Figure 2.13 shows the preference of graphic and IT students in their freshman and senior years for living room color (Hanafy and Sanad, 2015).

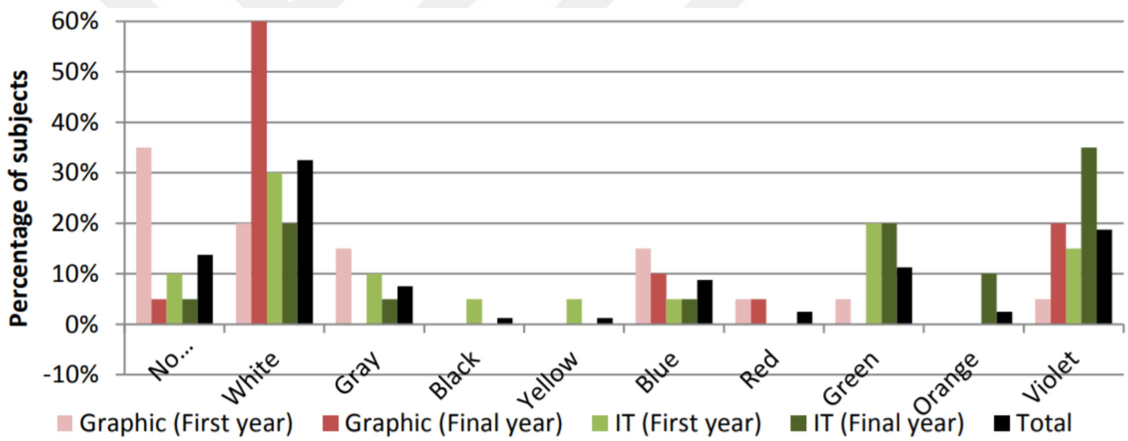

Figure 2.13: Students of different education levels and backgrounds preference of colors for a living room context (Hanafy and Sanad, 2015, p. 441)

2.3 Color and Human Performance

The results of different studies mainly form the idea that color generally affects the performance of the human in different ways. In one of the most specialized studies conducted in the United States and Germany, the impact of red color on performance was studied with the participation of 282 undergraduate students, and through six experiments. Three colors were chosen for the experiments, which are red, green (considered as contrast for red) and a neutral color (black, white and grey) (Elliot et al., 2007). Table 2.3 provides a summary of the experiments results and the impacts of the different colors.

Table 2.3: Experiments' results for the impact of red color on performance (Elliot et al., 2007, pp. 156-166)

Exp.	**Colors**	**Procedure**	**Testing for**	**Results**
1	Red Green Black	Test with distributed question difficulty	Task performance	Low scores for red colored test papers. Results for green and black papers were significantly higher and similar to each other
2	Red Green White	Test with distributed question difficulty	Task performance	Low scores for red colored test papers. Results for green and white papers were significantly higher and similar to each other
3	Red Green Grey	Answering questions marked with a certain color	Caution and vigilance	Low scores for red colored test papers. Results for green were the highest, while grey was the second highest.
4	Red Green Grey	Mood testing quiz before color marked questions	Avoidance and arousal	Lowest score for red colored tests. The green and grey tests have had significantly higher and same results as each other.
5	Red Green Grey	Answering a question on; how many easy questions you want out of 10?	Risk taking	Participants with red tests have indicated the highest number of easy questions, followed by green, then grey.
6	Red Green Grey	EEG test while taking test	Brain electrical activity	Frontal asymmetry was minus for the red color. Green and grey were positive and of an equal value.

The color assignment to students in the above experiments was random and changing between the different tests. Therefore, such results show the negative effects of the red color on human performance as the lowest score tests were always associated with the lowest test scores, lower tendency for risk taking and lower brain electrical activity. However, the green and neutral colors (black, white and grey) had minimal or no effect of the performance of the students in the six experiments (Elliot et al., 2007).

Furthermore, memory is considered one of the performance abilities that are needed for judgement and critical thinking during task performing. Thus, several researches have studied the impact of color on memory retention. In a study that experimented the ability of thirty graduate students to remember words associated with colors and shapes using three types of colors; shades of black and grey (achromatic), colors that are related to the words used in the experiment (congruent) and colors that are not related to the words used in the experiment (incongruent), the results of the study show that color is more effective in memory retention than the shape factor. Moreover, the scores of the experiment show that the students were able to recall words with the congruent colors 6% and 35% better than the achromatic and incongruent colors, respectively. While an ANOVA testing showed that the scores differences are significance to the 0.05 level (Olurinola and Tayo, 2015).

In a review of medical research, the authors mentioned that using color has a positive impact on the memory by 5% and 10%, compared to black and white, respectively. Moreover, increasing the contrast of the color has been reported to enhance the memory performance of the study subjects. When applying the same procedure to objects and words, color was able to increase the implicit and explicit memory performance. However, when using color as the background of the object or words of a black color, the white background color has shown the highest memory retention score among other colors, such as blue and green (Dzulkifli and Mustafar, 2013).

2.4 Color in Work Environment

While the impact of color of psychology have been explored in different contexts, the research of color in the work environment and offices is limited, which resulted into indefinite and fluctuating results (Lencher, Harrington, and Magusson, 2012). In a Malaysian study on color in offices, the researchers adopted a mixed methodology using a questionnaire and interview data collection streams. In the literature review, it was mentioned that the aim behind the color implementation in the work environment is to simulate involvement and ownership towards the goal of increasing productivity. Moreover, the productivity of the employees would basically depend on several factors including; individual interests and differences, social involvement, organizational structure and indoor environment. Therefore, the color implementation in the work environment would have a direct impact on the indoor environment, while individual and social factors are influenced by the work structure, culture and work environment (Kamaruzzaman and Zawawi, 2010).

The results of the study are collected from three office sections, where the total gender distribution is 58.1% and 41.9% for males and females, respectively. The participants agreed that their office needs a color change that can enhance their productivity and comfortability. The participants indicated with 40% that blue is their favorite color, while they perceive blue and green to be increasing the soothing and calming effect of the new proposed color change (Kamaruzzaman and Zawawi, 2010), as shown in Figure 2.14.

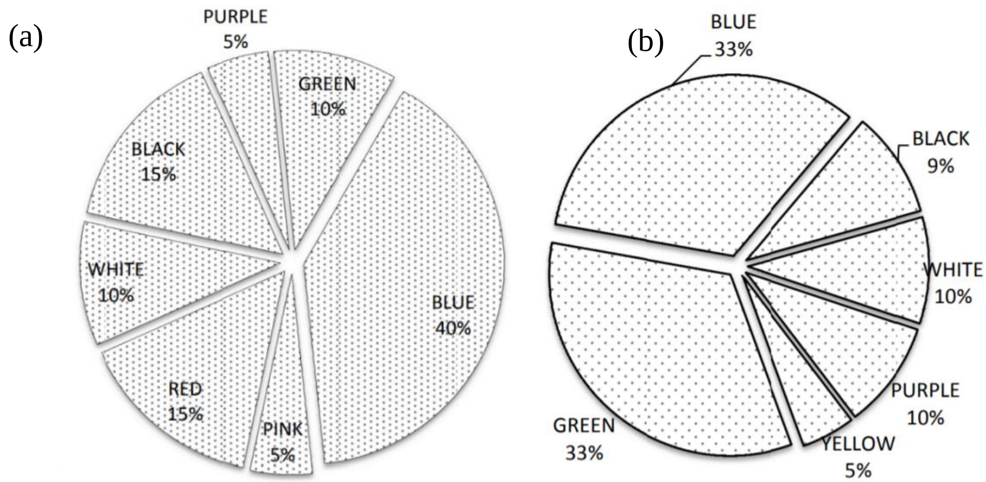

Figure 2.14: (a) Participants color preference (b) Participant perception for soothing and calming color for the proposed change (Kamaruzzaman and Zawawi, 2010, p. 292)

Nevertheless, a study by Kwallek (2005), which aimed to understand the effects of the color on office occupants in terms of well-being, productivity, performance and satisfaction, have implemented the color schemes on an actual work environment. Instead of implementing a sole color in the space, the specialist author has painted the confined office with three different color combinations in order to utilize the contrast; white, red contrasted with blue-green accent, and light blue contrasted with dark green and pink.

However, prior narrating the results the researcher has stated that few studies have concluded some solid results on preference, performance and satisfaction in the work environment due to the individual various responses by the employees. Therefore, the results state that the red room had the most negative effect on the low screener employees as it made them less productive, while the high screener employees found it exciting and they were more productive than the employees in the light blue office. Moreover, a relaxing effect was imposed in the blue office, which had a negative productivity impact on the high screeners (Kwallek, 2005). From the aforementioned study, we could confirm that the color impact on performance and productivity in the work environment is not only correlated the color and its properties, but also there are several other parameters that were mentioned in Figure 2.6 that shall be taken into consideration.

Since there is no complete consensus on the colors and their immediate effect on productivity and mood of the employees, as primary factors, there is no solid recommendations for the best fit color design for the office interiors. However, few studies have provided recommendations for the best fit colors according to the space functionality. Most of the work environments have been preferred to be painted with the white color in order to eliminate any distraction from the performed tasks. However, recommendations by specialists have mentioned the following color use for the specific tasks (Office Principles, 2014):

1. Blue shades for their positive and dynamic effect.
2. Green for their relationship with nature, which give an uplifting and calming effect depending on the individual.
3. Yellow shades for areas with natural lighting.
4. Red for areas where detailed work is performed due to its effect on increasing alertness.
5. Black and white for elegant and fashionable effects.

Some of these recommendations can be confirmed through the results of practical studies, where a red office and a blue-green office were compared in terms of the employees' productivity based on two activities that required narration and mathematical procedures. While the blue-green have shown higher productivity regarding narration activities in the first day of the week, the red office has increased the employees' productivity with the mathematical procedures in the middle of the week, which could be attributed to the color effect on sustaining alertness (Kwallek, Lewis, & Robbins, 1997). The study also took into consideration the individual differences between the employees, as shown in the comparison between the red and blue-green rooms in Figure 2.15, which shows the productivity of low and higher screeners on the first and fourth day of the study.

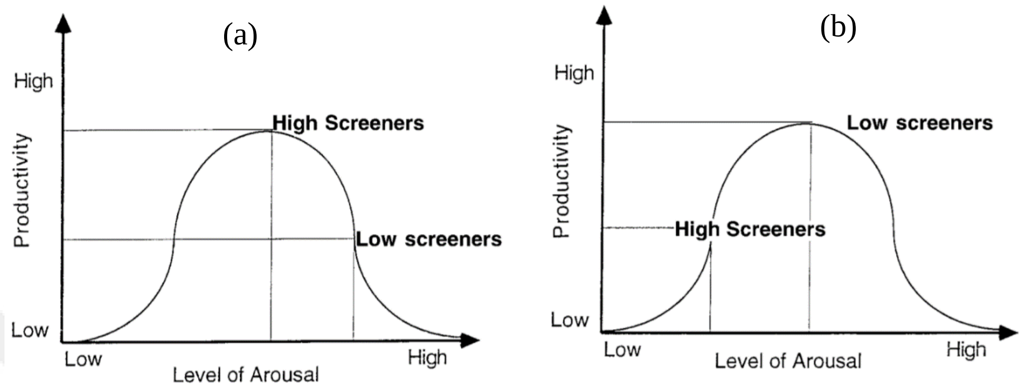

Figure 2.15: Level of arousal for low and high screeners on the first and fourth day (a) red room (b) blue-green room (Kwallek, Lewis, and Robbins, 1997, p. 130)

2.5 Color and Light Relationship

As mentioned earlier in the color theory and the explanation of Newton for the concept of color, the color and its properties emerge from the reflected light on any surface or object. Therefore, it can be said that the properties of the color affect the way an individual perceive the color. In a study that used light to give the space color, fifteen participants were put under tests that included readings for their heart rate and skin conductance, using four colors with different intensities; natural light, green low, green high, red low, red high, blue low, blue high, and white (Abbas, 2006). Table 2.4 shows the average heart rate for the participants under each light and color.

Table 2.4: Difference in heart rate by light and color (Abbas, 2006, p. 16)

	White	Blue-H	Blue-L	Green-H	Green-L	Red-H	Red-L	Natural
HR (Beat/min)	89.80	91.02	86.97	90.26	87.12	84.03	93.53	96.99

The results in the table show that the averages for the different colors and lights are different that each other, where the natural lighting had the highest heart rate and the red low light had the lowest heart rate mean. Moreover, the study conducted a skin conductance reading for the participants, which found that the participants had the highest skin conductance for the natural lighting, followed by the green low, red low, red high, blue high, white, blue low and green high, as shown in Figure 2.16 (Abbas, 2006). Those results show that humans react differently under different colors and light intensities on the physiological level, which means that the lighting can alter the way a person respond to the same color.

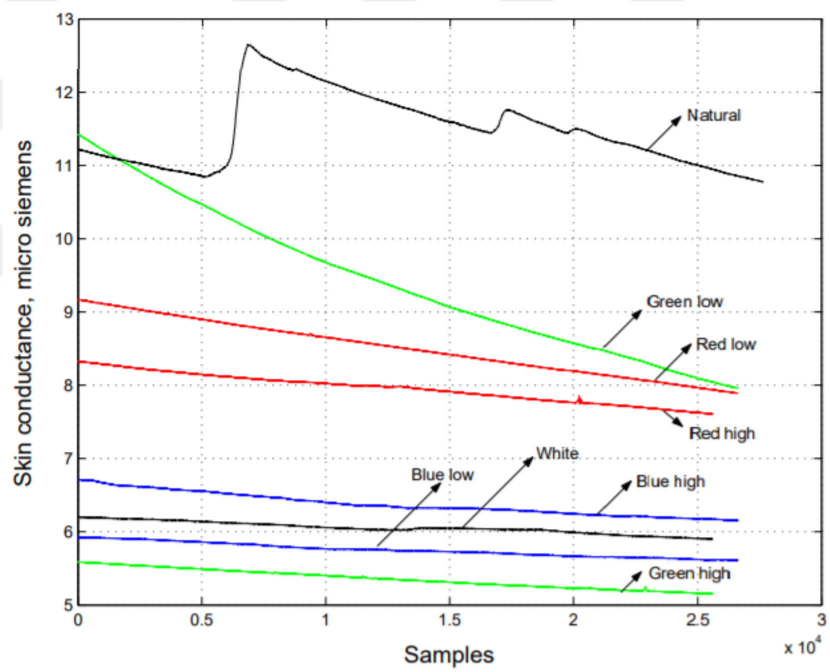

Figure 2.16: Skin conductance reaction for different color and light (Abbas, 2006, p. 19)

Furthermore, Sokolova and Fernandez-Caballero (2015) performed a review on color and light studies and developed a model on these factors' impacts on the performance of tasks and the emotional state of individuals. The results of the review show that lighting intensities change the way people react to the same colors. The differences were found in differences in gestures, body movements, facial expressions, speech efficiency and psychological state. The authors suggested that by understanding the impact of the lighting on the color, and both factors on individuals, the properties of color and lighting can be corrected in order to simulate the most effective state for humans in any context (Sokolova and Fernandez-Caballero, 2015).

Sarode and Shirsath (2014), identified five main elements of the interior that affect the productivity of the people in work environments, including; lighting, color, noise, air quality and furniture. The study focused that certain intensities of lighting, whether high or low, causes sight issues, headaches. On the color factor, the study confirmed that the different spaces within the work environment shall be incorporated with different colors according to the activities performed in each space. Moreover, the study concluded that color and lighting have a close relationship in forming the space, as both have aesthetic, psychological and physiological impacts on the space users (Sarode and Shirsath, 2014).

CHAPTER 3

CASE STUDY

This chapter provides the basis for the case study by structuring the study questions and hypotheses. Furthermore, the developed models are presented based on NCS color system, and the methodology design. Finally, the sample characteristics, source of errors and analysis techniques are presented.

3.1 Research Questions

The main question of this research is “How does the different selected colors (red, blue, black and white) based on NCS color system affect individuals in a work environment based on their performance and accuracy?” Moreover, based on the objectives of the research, the following questions are structured:

1. What are the differences between white and red colors in a work environment in terms of performance and accuracy?
2. What are the differences between white and blue colors in a work environment in terms of performance and accuracy?
3. What are the differences between black and red colors in a work environment in terms of performance and accuracy?
4. What are the differences between black and blue colors in a work environment in terms of performance and accuracy?

3.2 Hypotheses

The hypotheses of the study are structured to achieve the main aim and objectives of the research through the evaluation of the developed model and the subjective evaluation of the different colors in the work environment context. Therefore, the hypotheses are as the following:

H1: There is a statistical difference in performance within work environments between black and cool colors (i.e. blue), based on completion time of tasks and correct answers.

H2: There is a statistical difference in performance within work environments between white and cool colors (i.e. blue), based on completion time of tasks and correct answers.

H3: There is a statistical difference in performance within work environments between black and warm colors (i.e. red), based on completion time of tasks and correct answers.

H4: There is a statistical difference in performance within work environments between white and warm colors (i.e. red), based on completion time of tasks and correct answers.

3.3 Experiment Design and Participants

As reviewed in the literature, the effect of color on individuals within work environments is measured through their performance, which can be measured using the completion time needed to complete a task (productivity) and the correctness of the task performance (Kwallek, 2005; Kwallek, Lewis, and Robbins, 1997). According to the literature, the different aspects of performance can be measured through using an Intelligence Quotient (IQ) test questions, which can quantify the mental capacity of an individual according to the surrounding environment (Gondal and Husain, 2013). Moreover, the IQ test has been used in several studies to measure the performance in educational and work environments (Gondal and Husain, 2013; Grinblatt, Keloharju, and Linnainmaa, 2011).

Therefore, two test forms (Appendix A) were designed in order to measure the performance of the participants in the study under different colors by simulating an administrative work environment. The tests have been designed with fifteen questions for each form, where the questions are divided equally according to their difficulty; easy, moderate, and hard. Furthermore, the test questions are compiled using a book specialized in designing IQ test questions according to their type and difficulty (Carter, 2005). Other tools are used in the experiment including a stopwatch in order to measure the completion time of each participant for the test, and workstation cubicles, which are colored with the different colors included in this study.

The participants of the study are randomly selected from the students using the library at the main campus of Çankaya University, of both genders (25 males and 25 females), and their age ranges between 19 to 26 years old. The random selection is based on the fact that the results of individual participants is compared to his or her own performance between the two cubicles. Therefore, the procedure is explained to the participants prior starting the experiment, proceeded to the first cubicle with white or black colours, and then proceeded to the second cubicle with red or blue colours. The choice of colour is made random; however, the participants are distributed such that an equal number of results is provided of the four scenario variations.

3.4 Color Notations

The colors used in this study were standard NCS colors. Nonetheless, the colors chosen were black and white as neutral colors, red as a warm color, and blue as a cool color. The literature shows that red is one of the most influential colors on the performance of humans (Elliot et al., 2007), while the blue color is often chosen as the favorite colors in different environments and studies (Cohen, 2013; Ellis and Ficek, 2001; Terwogt and Hoeksma, 1995). Black and white are often used as neutral color for comparison with other colors in the color systems (Bakker et al., 2015; Al-Rasheed, 2015).

Furthermore, the experiment environment is set by using cubicles, each covered with one of the four colors used in this study. Figures 3.1, 3.2, 3.3 and 3.4 show the different color installations used in the research. The color installation was performed using a painted paper cover on the plain cubicle desk as shown in the figures. The NCS color notations used for the four colors are:

1. White: NCS S 0500-N
2. Black: NCS S 9000-N
3. Blue: NCS S 1060-B
4. Red: NCS S 0585-Y80R

Figure 3.1: Work environment simulation in Black (S 9000-N)

Figure 3.2: Work environment simulation in White (S 0500-N)

Figure 3.3: Work environment simulation in Red (S 0585-Y80R)

Figure 3.4: Work environment simulation in Blue (S 1060-B)

The lighting at the cubical was florescent lighting, as well as natural lighting at the library, and the participants performed the experiment between 8:00 am and 4:00 pm. Figure 3.5 shows pictures from the library, where the study was conducted, which illustrates the lighting type in the space. It is apparent that the lighting in the library consists of both artificial and natural lighting coming through full-panel windows.

Figure 3.5: Lighting in the library of Çankaya University main campus

3.5 Procedure and Data Analysis

The procedure of the experiment was modified from Elliot, et al. (2007); however, the procedure was used to evaluate the differences between four colors within the work environment. The location of the experiment is chosen as the library of the main campus of Çankaya University in Ankara, where the tools were set up using the cubicles provided in the building. The painted papers with four NCS colors (black, white, red and blue) were prepared in advance to suite the dimensions of the workstation cubicle. Fifty participants were involved in the study, as each participant was planned to take the first form of the performance test (form 1) at one of the neutral colors, and then move to take the second form of the performance test (form 2) at either blue or red color.

The participant was first introduced to the study and the procedure, then moved to take the first test. At the beginning of the answering process, the participant was assigned to a unique participant number, and the stopwatch was reset and started. Upon the completion of the test, the stopwatch was stopped, and the elapsed time was recorded at the test form. The participant was given few minutes to rest and then moved to the second color with the second performance test form, where the same procedure was carried out.

The results of the test were entered into SPSS for analysis, where a paired comparison between the performance of the individual participant was analyzed using a paired samples t-test, and the differences between the four colors were measured independently, using a one-way ANOVA analysis. The main goal of using these tests was to measure the differences of the individual performances, as well as the difference between the four colors based on the results; completion time and correctness of completing the task.

3.6 Results and Findings

Considering the results for the four colors independently, a mean comparison was conducted between the four cases as shown in Figure 3.6 through a histogram of the completion times of the performance tests. The results show that the blue color had the lowest completion mean time of seven minutes and 57 seconds. Individual results for each participant are shown in a table in Appendix B.

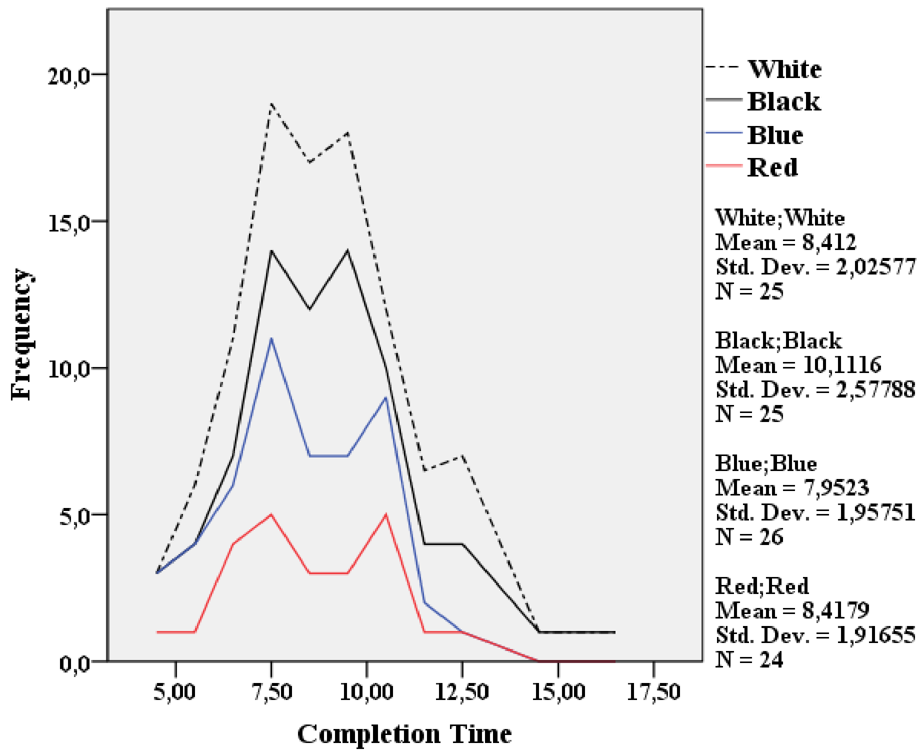

Figure 3.6: Histogram of completion time for the different colors

The blue color was followed by the white color (eight minutes and 24 seconds), red color (eight minutes and 25 seconds), and black color (10 minutes and seven seconds), as decimals were converted to seconds. Based on the correctness in completing the performance test, the white color had mean correct answers of 9.28 as the highest average score, as shown in the histogram in Figure 3.7. The white color was followed by the red color with a mean of nine correct answers, then blue (8.88 correct answers) and black (8.68 correct answers). The above results indicate the black color with the lowest performance simulator in the work environment. Nonetheless, while the blue color was the most productive color on the productivity factor, the white color had the most effect on the accuracy of the work produced by the participants, as seen by comparing graphs 3.6 and 3.7.

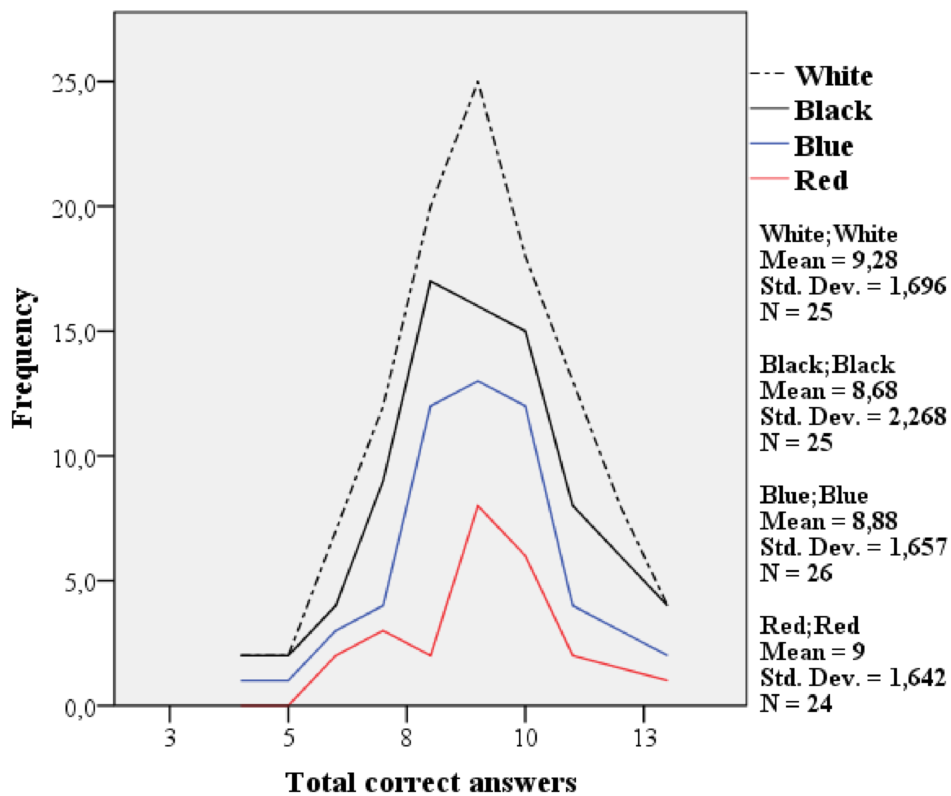

Figure 3.7: Histogram of the correctness in completion of the task for the different colors

In order to understand the general differences in performance between the four colors used in this study, a one-way ANOVA was conducted for the results independently (without considering the tests taken by the same participants). As shown in Table 3.1, there were significant difference between the colors based on the completion time (sig.= 0.003), the correct answers of the easy level questions (sig.= 0.002), and the correct answers of the hard level questions (sig.= 0.028), at a confidence level of $p < 0.05$.

Table 3.1: One-way ANOVA test for differences between the four colors independently ($p<0.05$)

		Sum of Squares	df	Mean Square	F	Sig.
Completion Time	Between Groups	68,298	3	22,766	4,987	,003
	Within Groups	438,259	96	4,565		
	Total	506,558	99			
Easy Level	Between Groups	10,038	3	3,346	5,277	,002
	Within Groups	60,872	96	,634		
	Total	70,910	99			
Moderate Level	Between Groups	4,652	3	1,551	1,369	,257
	Within Groups	108,738	96	1,133		
	Total	113,390	99			
Hard Level	Between Groups	14,144	3	4,715	3,177	,028
	Within Groups	142,446	96	1,484		
	Total	156,590	99			
Total correct answers	Between Groups	4,706	3	1,569	,466	,707
	Within Groups	323,134	96	3,366		
	Total	327,840	99			

To understand the nature of the differences between the colors, a post-hoc testing was performed, as shown in Table 3.2, where the main difference in completion time was between the black and blue colors, as the blue color had less completion time (higher productivity). For the easy level questions, the blue and red colors have significant differences with the white color, which had a higher correctness rate.

Table 3.2: Post-Hoc test for differences between colors independently (p<0.05)

Dependent Variable	Variable i	Variable j	Mean difference (i-j)	Std. Error	Sig.
Completion time	Black	Blue	2.15929	0.59849	0.007
Easy Level	White	Blue	0.745	0.223	0.014
	White	Red	0.652	0.228	0.048

As each of the fifty participants have taken two performance tests, one for neutral and another for a warm or cool color, it was important to compare the results of the two tests in order to understand the impact of the color change on the performance, productivity and correctness of completing the task. As shown in Table 3.3, where the results of the tests were compared for the participants who took white as a neutral color and blue as a cold color, a paired sample t-test was performed. The results showed that there were significant differences at the confidence level of $p < 0.05$ in terms of the completion time (sig. 0.011), correct answers for the easy level questions (sig. 0.035), and correct answers for the hard level questions (0.008).

The mean differences indicate that the blue color had a less completion time than the white color (higher productivity). In regard to the answers' correctness, the white color had a higher rate than the blue color for the easy questions, while the blue color had a higher correctness rate than the white color for the hard questions, which were indicated through the positive (0.714) and negative (-1.071) mean differences, respectively.

Table 3.3: Paired Samples t-test for differences between W = White and B = Blue at $p<0.05$

	Paired Differences							
	Mean (W-B)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper	t	df	Sig. (2-tailed)
Completion time	1,80929	2,29724	,61396	,48290	3,13567	2,947	13	,011
Easy level	,714	1,139	,304	,057	1,372	2,347	13	,035
Moderate level	,571	1,399	,374	-,236	1,379	1,529	13	,150
Hard level	-1,071	1,269	,339	-1,804	-,339	-3,160	13	,008
Total correct answers	,214	2,293	,613	-1,110	1,538	,350	13	,732

Furthermore, on applying the same test to the case of white and red colors, shown in Table 3.4, there were no significant differences between the results of the two colors at a confidence level of $p < 0.05$. Nonetheless, the mean differences show that the red color had a higher productivity rate over the white color, as shown from the negative mean difference (-1.2946). Similarly, the red color had a higher correctness rate for the hard questions, as understood from the negative mean difference (-0.636). However, these results are not considered statistically significant according to the paired sample t-test.

Table 3.4: Paired Samples t-test for differences between W = White and R = Red at $p<0.05$

	Paired Differences							
	Mean (W-R)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper	t	df	Sig. (2-tailed)
Completion time	-1,2946	3,00396	,90573	-3,3126	,72354	-1,429	10	,183
Easy level	,455	1,293	,390	-,414	1,323	1,166	10	,271
Moderate level	,364	1,502	,453	-,645	1,372	,803	10	,441
Hard level	-,636	1,859	,560	-1,885	,612	-1,136	10	,283
Total correct answers	,091	2,119	,639	-1,333	1,515	,142	10	,890

Furthermore, a paired sample t-test was conducted for the difference between the results of the black color performance tests and the blue color performance tests, as shown in Table 3.5. None of the parameters had a significant difference based on a confidence level of $p<0.05$. Nevertheless, the mean difference of the completion time (productivity) was positive (1.7833), which indicates a higher productivity rate for the black color over the blue color. Moreover, the negative mean difference shown for the correctness of answers under the moderate and hard questions indicate that the blue color increased the correctness of these answers. However, none of the differences between the black and blue color were considered significant at the research's confidence level.

Table 3.5: Paired Samples t-test for differences between K= Black and B= Blue at p<0.05

	Paired Differences							
	Mean (K-B)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper	t	df	Sig. (2-tailed)
Completion time	1,78333	3,26401	,94224	-,29052	3,85719	1,893	11	,085
Easy level	,750	1,357	,392	-,112	1,612	1,915	11	,082
Moderate level	-,250	1,545	,446	-1,232	,732	-,561	11	,586
Hard level	-,333	1,969	,569	-1,585	,918	-,586	11	,570
Total correct answers	,167	3,326	,960	-1,946	2,280	,174	11	,865

The final paired sample t-test was applied to the paired results of the black and red colors, where a significant difference was found between them in terms of the completion time of the performance tests. Such results indicate that black color had a higher productivity rate than the red color, through a positive mean difference of 1.677, as shown in Table 3.6. Moreover, a negative mean difference of -0.846 is calculated for the correctness of the answers to the hard questions, indicating a higher correctness rate for the red color. However, this result is not considered statistically significant at the confidence level of $p<0.05$.

Table 3.6: Paired Samples t-test for differences between K = Black and R = Red at $p<0.05$

	Paired Differences							
	Mean (K-R)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper	t	df	Sig. (2-tailed)
Completion time	1,67769	2,65367	,73600	,07409	3,28129	2,279	12	,042
Easy level	,538	1,450	,402	-,338	1,415	1,339	12	,205
Moderate level	,000	1,581	,439	-,955	,955	,000	12	1,000
Hard level	-,846	1,519	,421	-1,764	,072	-2,008	12	,068
Total correct answers	-,308	2,394	,664	-1,754	1,139	-,463	12	,651

3.7 Discussion

As shown from the case study results, several significant differences were found in terms of productivity and correctness in performing tasks between the four colors; white, black, red, and blue. The general differences found in Table 3.1 in terms of completion time, and the easy and hard level questions' answers show that participants were influenced by the surrounding color simulating the work environment. These results confirm the findings of the literature, where the study of Jalil, Yunus and Said (2012) have found positive impacts on wellbeing, and red and blue simulate excitement. Moreover, different emotional effects were found for the different colors under the study of Schaie (1966), as red simulated excitement, intensity and strong feelings. Blue simulated cool, control and comfort, while black and white simulated intensity and purity, respectively. A post-hoc analysis shows that black influences a higher productivity rate over blue, which contradicts the recommendations of Office Principles (2014) of the blue color increasing the dynamic effect. Another post-hoc analysis shows that white increased the accuracy in performing tasks regarding the easy level questions over the blue and red colors, it is confirmed through the literature that the white color has a positive impact; however, such findings contradict other recommendations of using the blue and red colors for different functionalities in the work environment.

However, the first part of the analysis (Table 3.1) do not show the differences for individual participants, rather than a general comparison between the results. Tables 3.2 to 3.6 shows a t-test results for the different scenarios that were experienced by the individual participants, which are:

1. Black then blue
2. Black then red
3. White then blue
4. White then red

Considering a confidence level of 95% ($p<0.05$), white then blue and black then red are the scenarios that yielded significant results, as shown in tables 3.4 and 3.6, respectively. The white color showed a higher productivity rate and correctness rate than the blue color, while the black color showed a higher productivity rate in comparison with the red color. Nonetheless, important mean differences were found, where the blue color increased the correct answers for the hard level questions, which shows that it could help increasing the control over the performed task as confirmed by Schaie (1966). Such a result can also confirm the recommendations of Office Principles (2014) to use the blue color in the work environments. Similar results were also found for the red color, in both cases, and especially in comparison with the black color. Office Principles (2014) recommends using the red color in meeting rooms and workshops as it increases alertness.

In the study of Elliot et al. (2007), the study focused on the impacts of the red color on the human performance, as well as comparing the results with neutral colors including white and black. The results of Elliot et al. (2007) showed low scores for the red colors in comparison with the significantly higher black color scores. The results of the present study show that a neutral color like white had the highest scoring. However, the red and blue colors had higher scores than the black color, as shown in Figure 3.2, which contradicts the results of Elliot et al. (2007). These contradictions could be attributed to the difference in the color implementation methodology, as the color was surrounding the participants in the present study, while the study of Elliot et al. (2007) presented the color at the cover page of the questions' cover. Nonetheless, since the scorings were higher in the blue and red cases specifically at the hard questions, such results could be caused by the higher alertness that is mentioned by Office Principles (2014), which helped the participants increases their mental presence for this part of the performance test.

Although there were important mean differences regarding the differences in performance between the red and blue, and the neutral colors, these colors could not achieve a significance level of $p<0.05$ on the paired sample t-tests. It is noticed through the manual comparison of the individual responses that the red and blue colors did not always increase the scores, which is attributed to the individual differences in the level of arousal of the participants, as discussed by Kwallek, Lewis & Robbins (1997).

In order to answer the research questions and test the hypotheses, an experimental methodology is conducted to measure performance and accuracy. A simulation of a work environment with four colors from the NCS color system was set up. Moreover, a performance test based on IQ questions with different difficulty levels were given to fifty participants, as each participant took different test forms for both a neutral, a cool or warm color. The colors are chosen because of their common disputed results in the literature. In order to reach the required results, four hypotheses are tested:

- H1: There is a statistical difference in performance within work environments between black color and cold colors (blue), based on completion time of tasks and correct answers.

  As shown in Tables 3.1 and 3.2, a one-way ANOVA and a post-hoc testing on general data shows that the completion time of black and blue are significantly different from each other (sig. 0.007) based on a confidence level of 95% ($p<0.05$). however, the individual results in Table 3.5, important mean differences indicate that black has better productivity rate, while blue increases the ability to perform tasks accurately. Therefore, this hypothesis is accepted.
- H2: There is a statistical difference in performance within work environments between white color and cold colors (blue), based on completion time of tasks and correct answers.

  As shown in Tables 3.1 and 3.2, a one-way ANOVA and a post-hoc testing on general data shows that the correctness of the easy level questions of white and blue are significantly different from each other (sig. 0.014) based on a confidence level of 95% ($p<0.05$). Moreover, the individual results in Table 4.3, indicate significant differences between the white and blue color based on productivity (completion time) and correctness of answered questions (accuracy). Therefore, this hypothesis is accepted.
- H3: There is a statistical difference in performance within work environments between black color and hot colors (red), based on completion time of tasks and correct answers.

  As shown in Tables 3.6, a pair sample of paired individuals' responses show a significant difference in productivity rate between the black and red colors' results, where the black color has a better impact on productivity. Moreover, an important mean difference is noted as the red color tends to increase the accuracy of the performed tasks. Therefore, based on a significance level of $p<0.05$, this hypothesis is accepted.

- H4: There is a statistical difference in performance within work environments between white color and hot colors (red), based on completion time of tasks and correct answers.

As shown in Tables 3.1 and 3.2, a one-way ANOVA and a post-hoc testing on general data shows that the correctness of the easy level questions of white and red are significantly different from each other (sig. 0.048) based on a confidence level of 95% ($p<0.05$). Moreover, the individual results in Table 3.4, indicate mean differences between the white and red color based on productivity (completion time) and correctness of answered questions (accuracy). Therefore, this hypothesis is accepted.

CHAPTER 4

CONCLUSION

The impact of the color on the human performance is known through several researches that confirmed its impact in different applications. The main goal of this type of research emerges from the desire of corporations to understand the different factors that affect the productivity of their employees and the performance of the company in general. In the business environment, the employees are considered as important assets, who are affected by the increasing stress levels. Therefore, these has been a special attention paid to the interior work environment from different perspectives. Despite the many studies that researched the impact of color, there has been no consensus on the effects of a single color on the human performance in different contexts.

The main aim of this research was to study the effect of color in work environments on individuals and find the significant differences between chromatic and achromatic colors using an experimental methodology. Thus, the study commenced by reviewing the literature in order to understand color, its properties, and its general and specific impacts on the human performance. Color has been explained through several approaches; however, the main properties of color are intensity, saturation and value, which gives it the various temperatures, shades and effects. Moreover, these are several standards that attempted to develop a system to describe the different properties of a certain color, including the NCS color system and Munsell color system. In this study the colors used in the case study are chosen based on the NCS color system, which communicates the different colors by coding them according to their hue, chromaticness, and blackness.

This explanation, and through the more detailed literature review, answers the first research question about the color systems and the way they communicate color.

Furthermore, studies have discussed the psychological and physiological impacts of color on the human mind and body. While colors like green had a relaxing effect on the blood vessels, other studies have found different colors related to the wellbeing and performance, negativity and positivity, mental alertness, and stress levels. Several levels of interaction of the human with the color are described in Talaei (2013), who stated that the first level of interaction with color is biological, then psychological. After that the color takes different effects depending on the culture, society and individual interests of each human. In this research and as part of the third research question, the relation between color and the space perception is explained, as color affects the human perception of the spaciousness and shapes within a certain space.

Several studies have tried to associate certain colors to certain emotions and human traits. For instance, while red is generally associated with excitement, activeness, and intensity, other colors had their own assignment of emotions, which differed from a study to another. There are factors that affect the preference of color based on personal characteristics, such as gender, level of education, age, and cultural background. However, the impact of color on human performance has been merely addressed in the literature, and specifically for the application on the work environments. Various methodologies have been used to understand the impact, while objective methodologies have yielded the most accurate and needed results.

Based on the results of this study, it can be recommended that in work environments, neutral colors, including black and white, should be used in general working areas, where the productivity rate is prioritized. However, cool and warm colors, including blue and red, can be used in meeting workshop areas, where accuracy and intensity is needed for the quality of the job. Finally, future research is recommended for this topic, possibly by using different colors, color systems, or methodologies.

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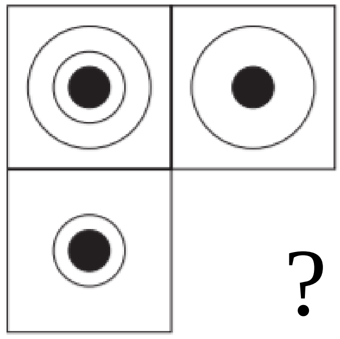
APPENDIX A

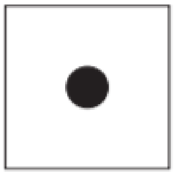
(PERFORMANCE TEST FORMS)

FORM 1

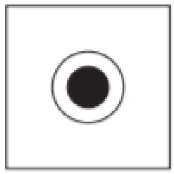
PARTICIPANT NUMBER	
COLOR	
TIME	

Q1





A



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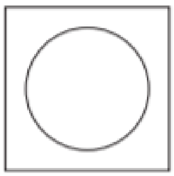

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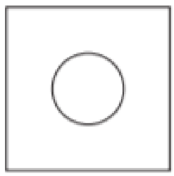
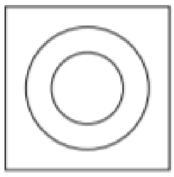


D

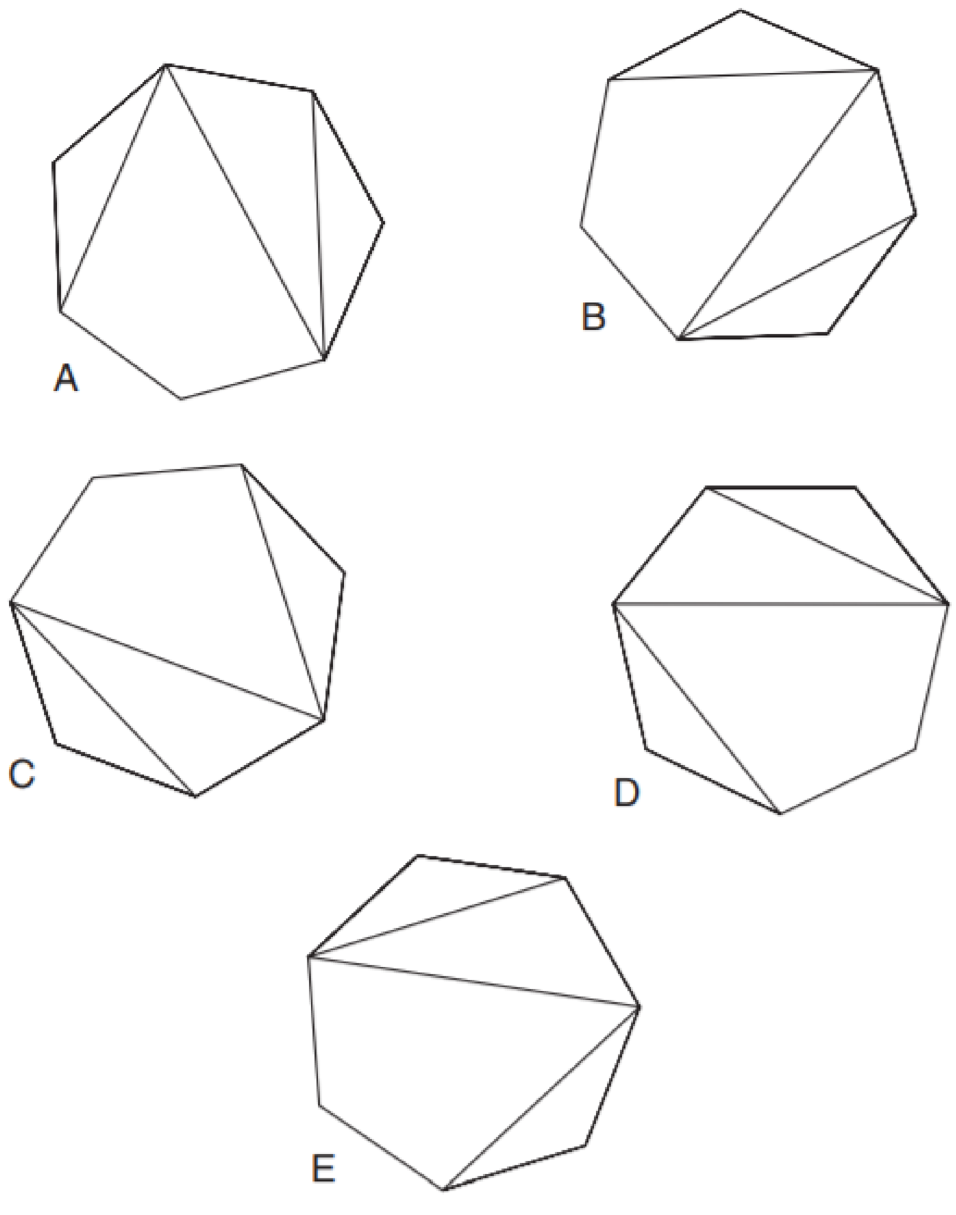


E

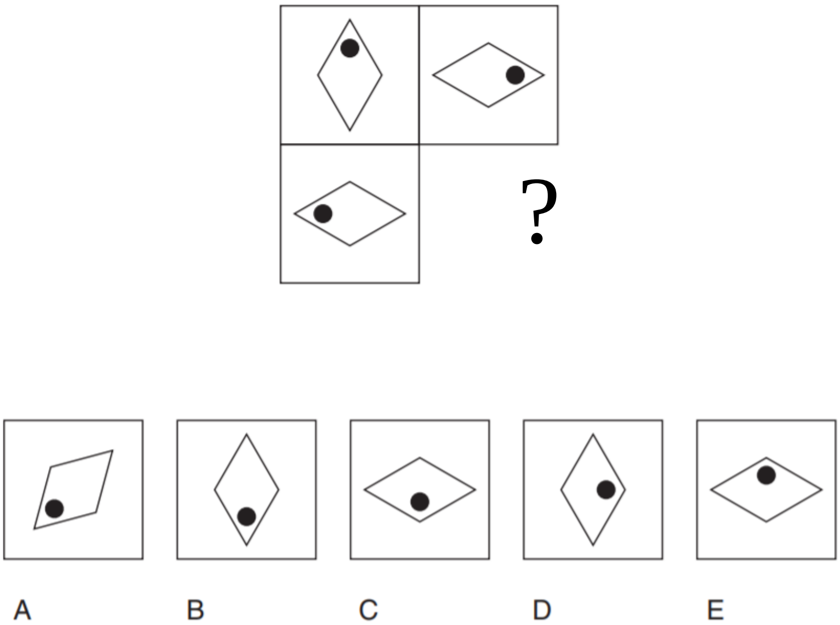
Q2

Which shape is different?

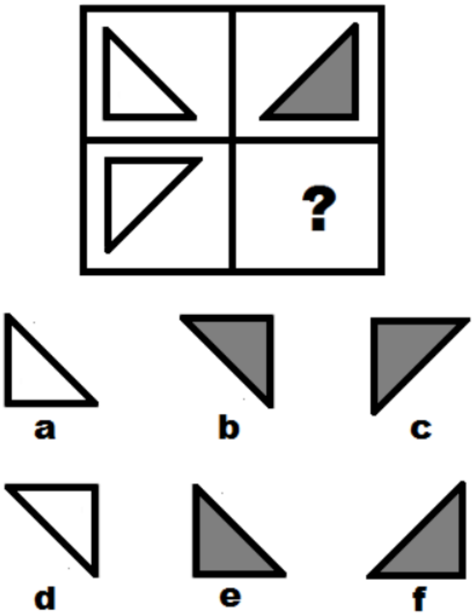
Hangi şekil farklı?



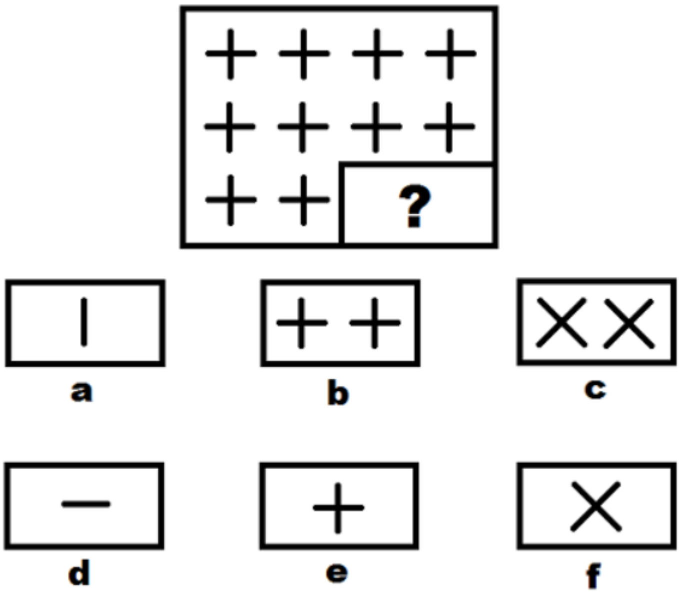
Q3



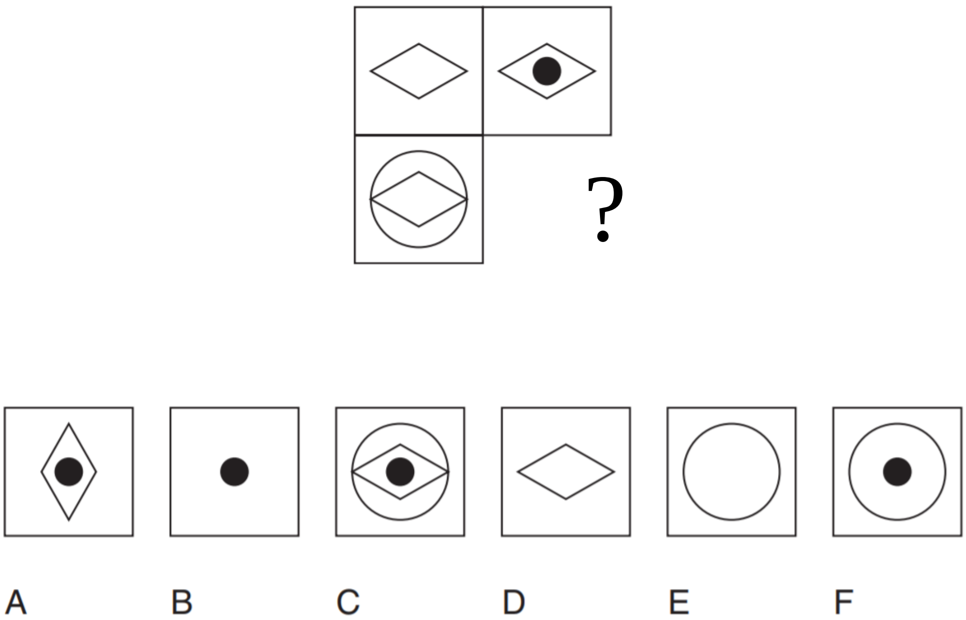
Q4



Q5



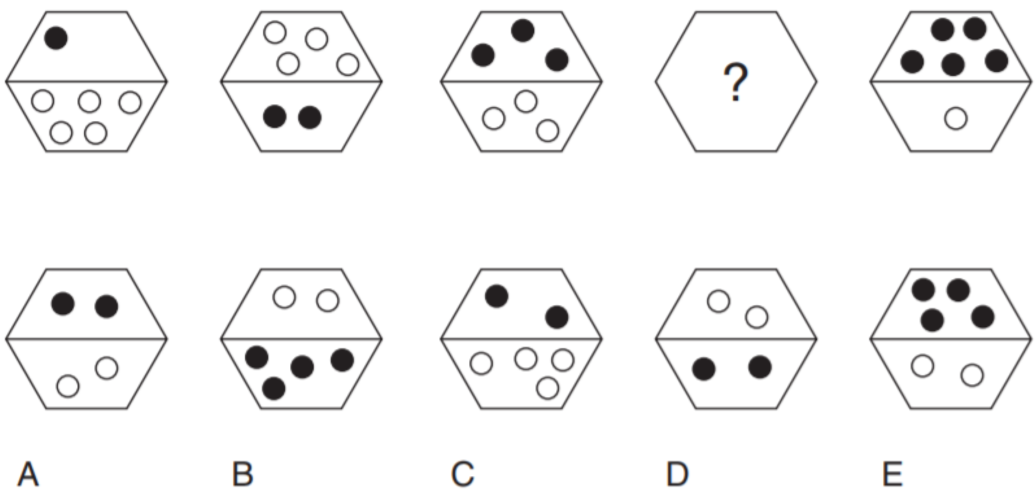
Q6



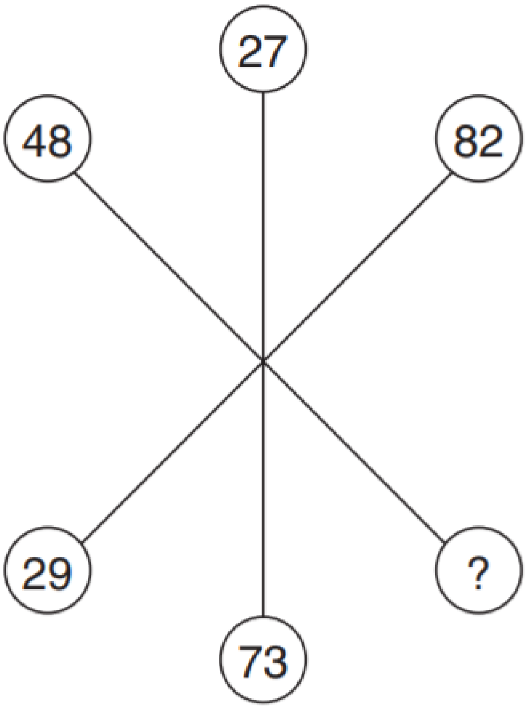
Q7

7	8	4	19
3	14	5	22
2	7	?	27
12	29	27	?

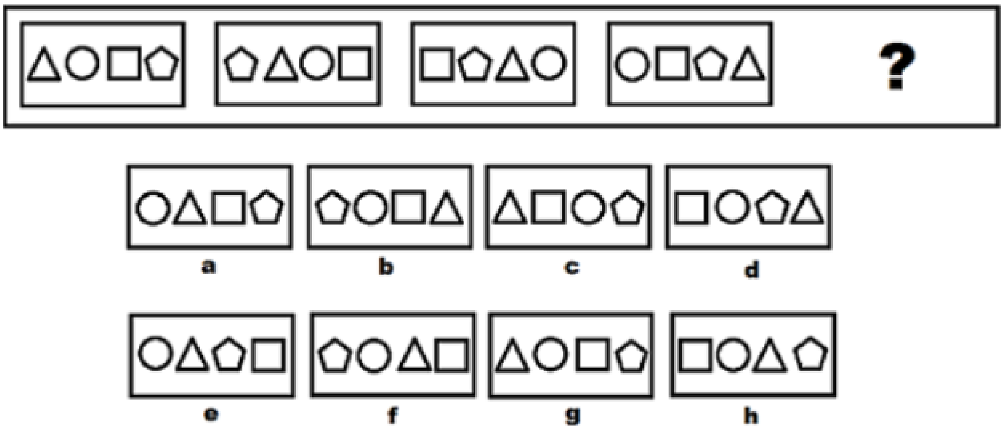
Q8



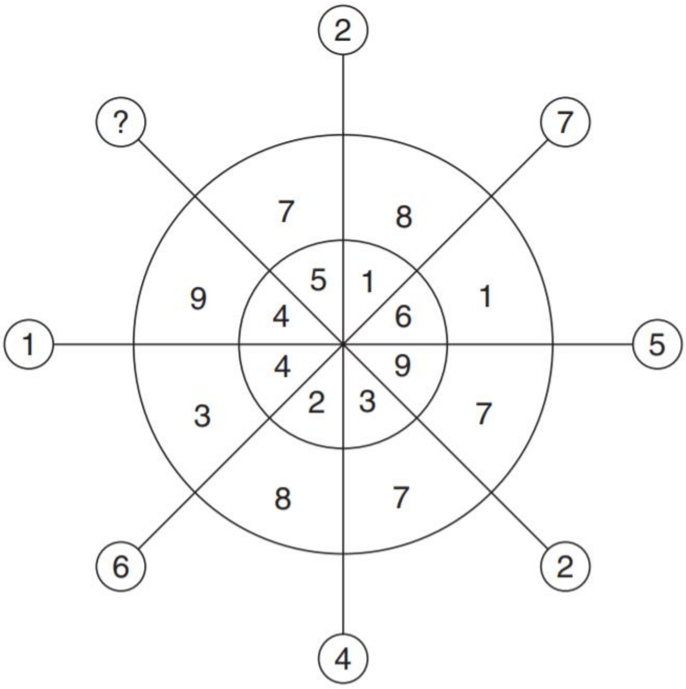
Q9



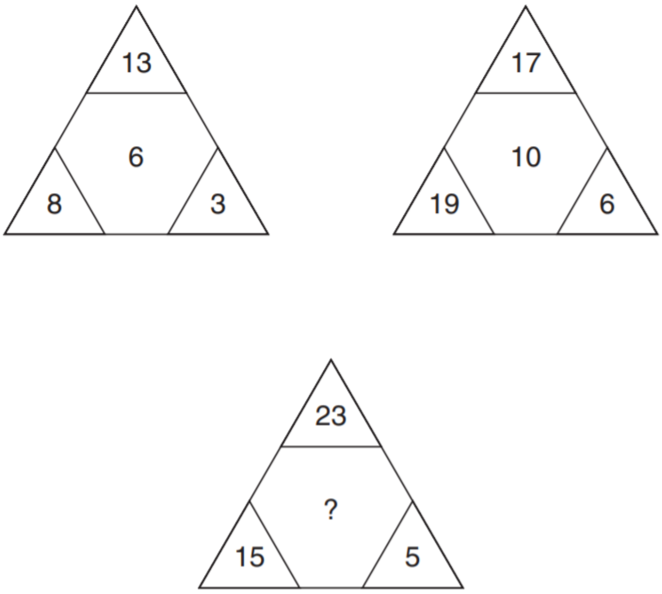
Q10



Q11



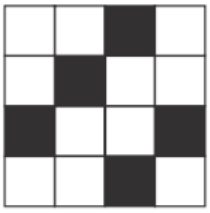
Q12



Q13

Which shape is different?

Hangi şekil farklı?



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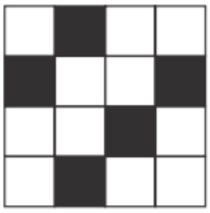
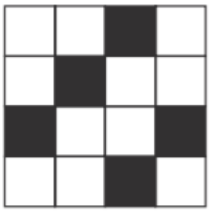
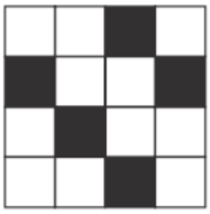


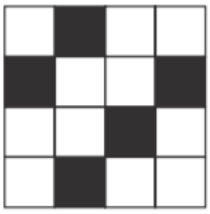
2



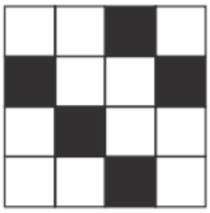
3



4

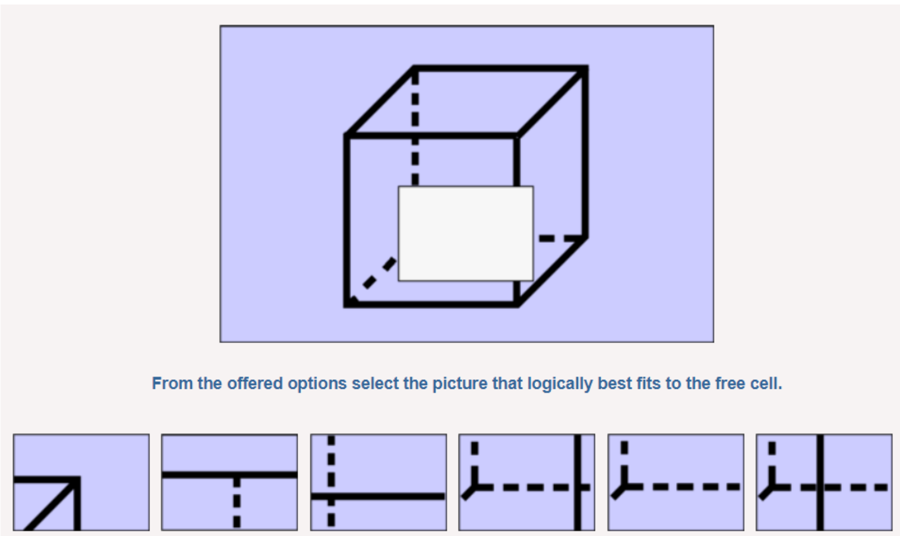


5



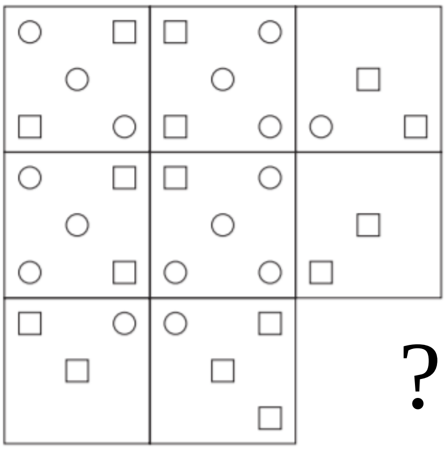
6

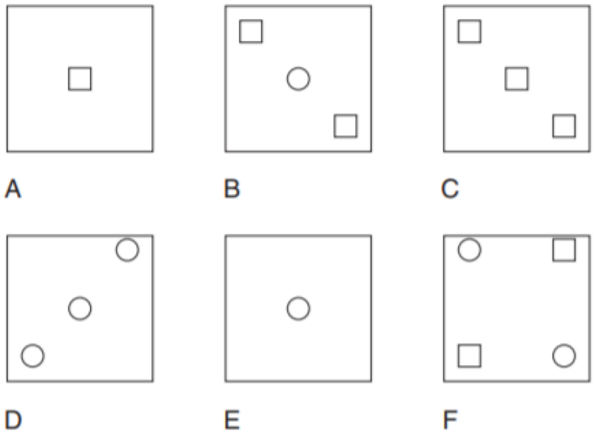
Q14



A B C D E F

Q15

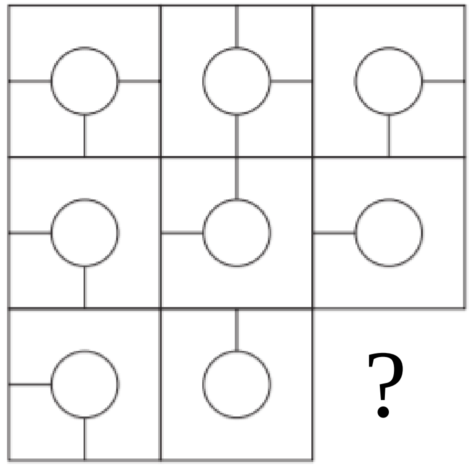


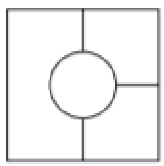


FORM 2

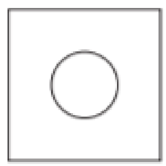
PARTICIPANT NUMBER	
COLOR	
TIME	

Q1

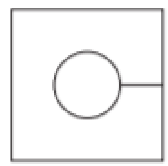




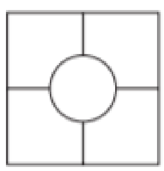
A



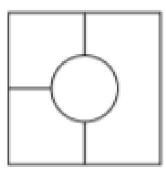
B



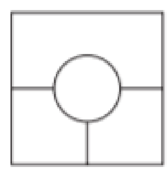
C



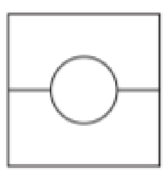
D



E



F



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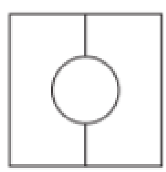
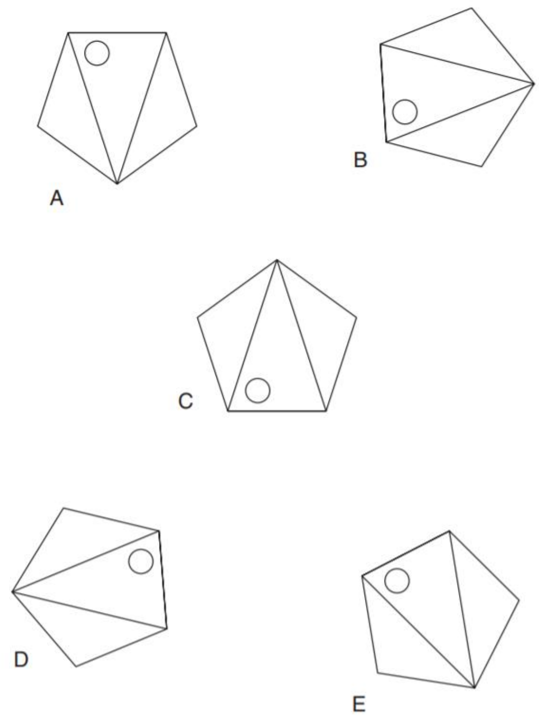


H

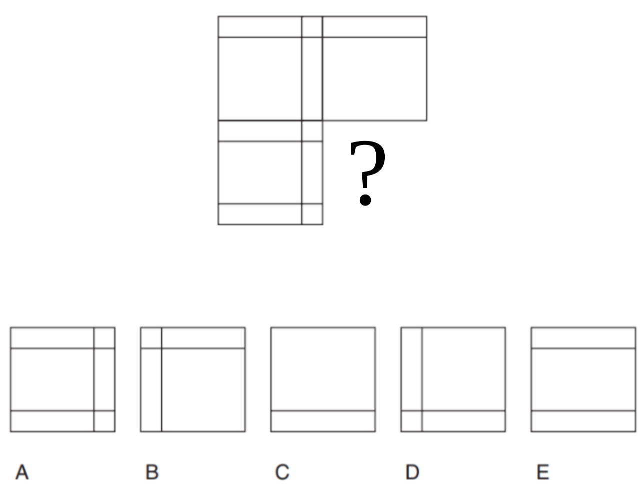
Q2

Which shape is different?

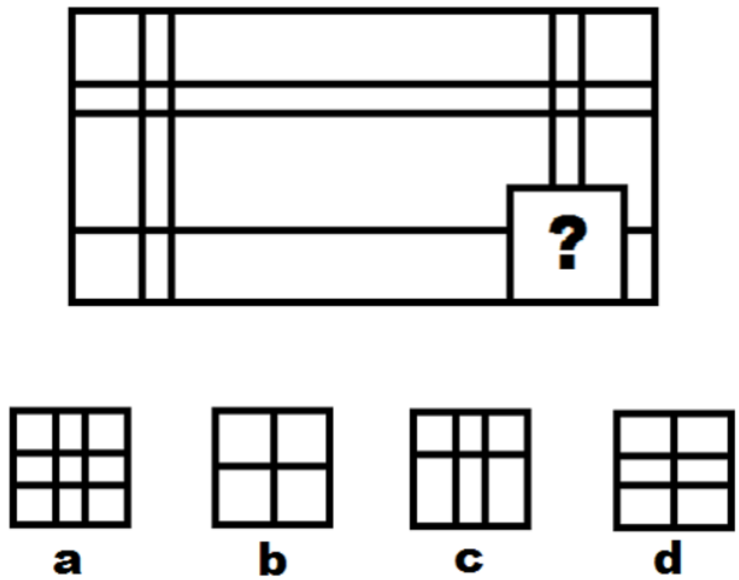
Hangi şekil farklı?



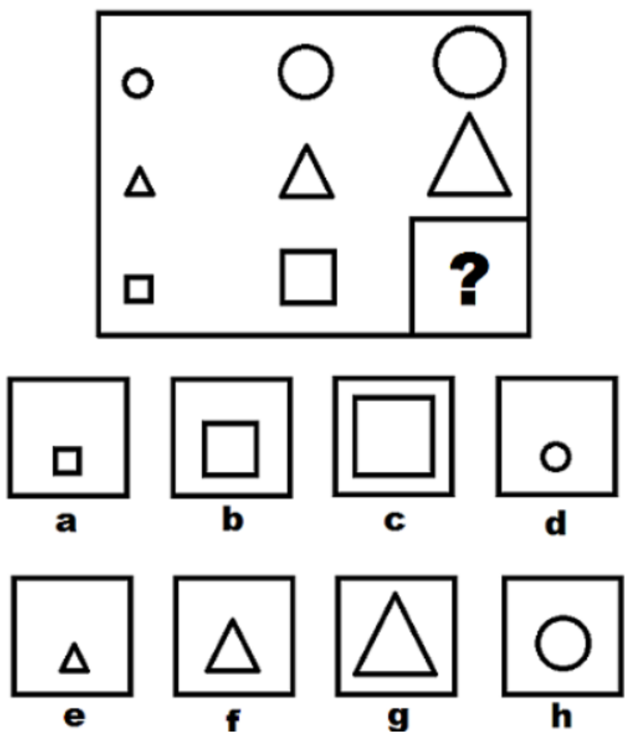
Q3



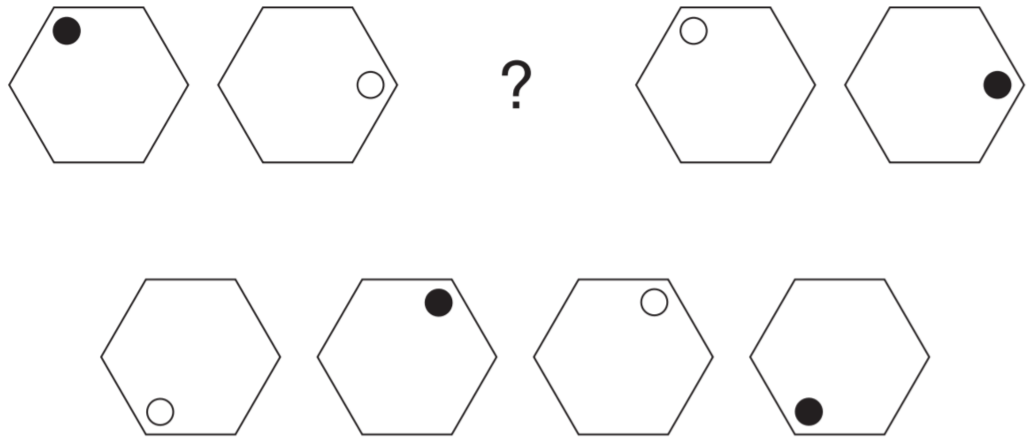
Q4



Q5

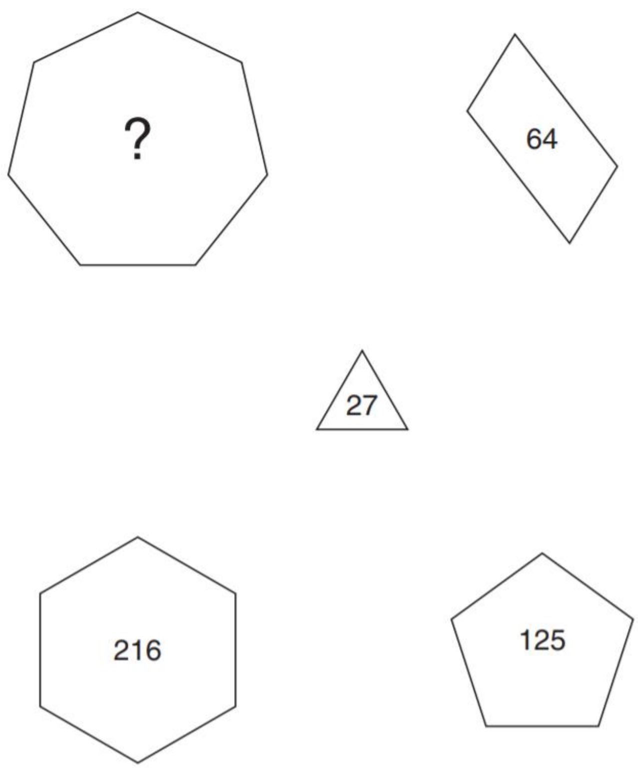


Q6

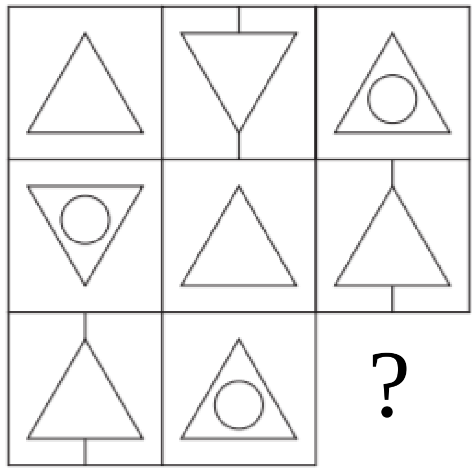


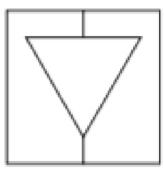
A B C D

Q7

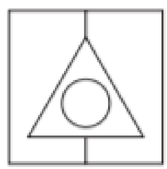


Q8

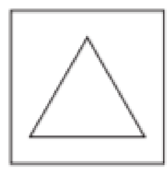




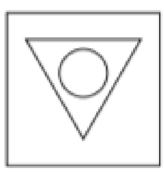
A



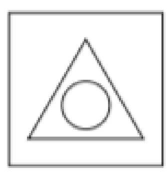
B



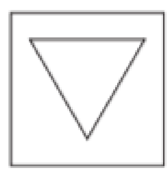
C



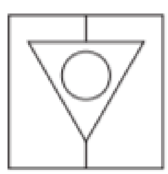
D



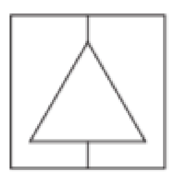
E



F



G

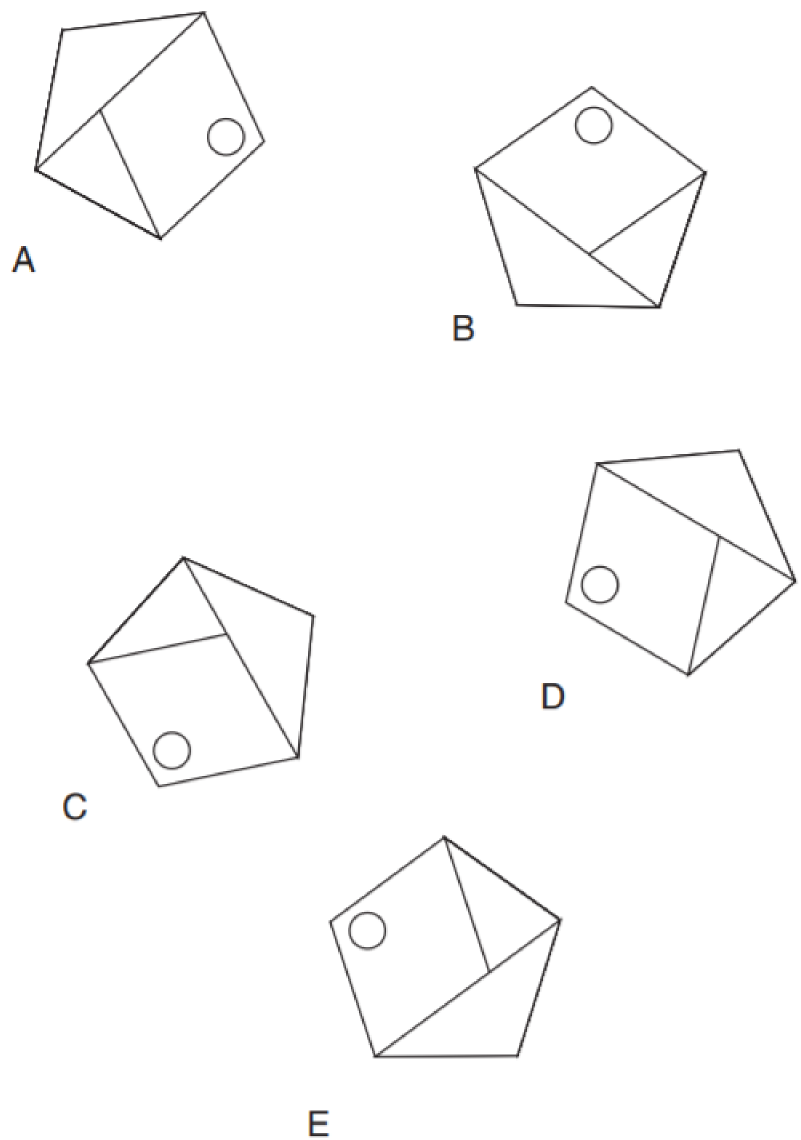


H

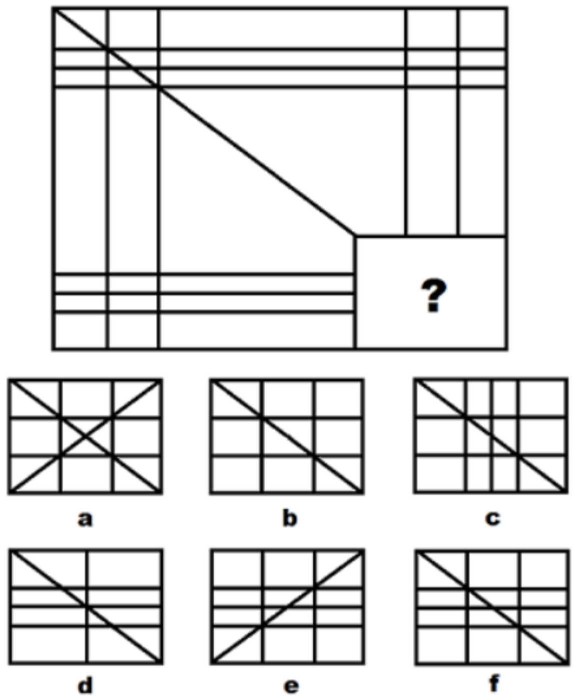
Q9

Which shape is different?

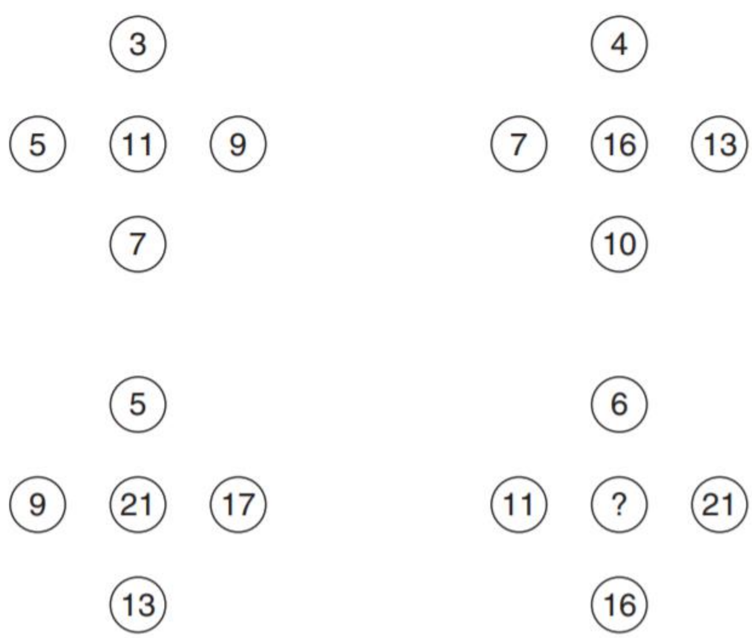
Hangi şekil farklı?



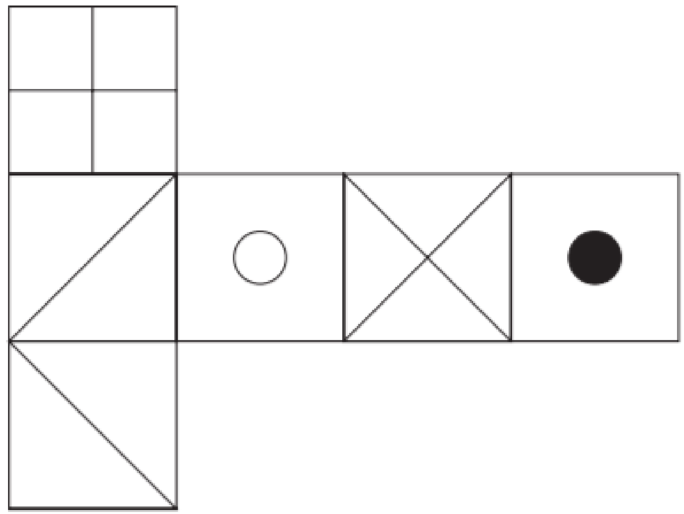
Q10



Q11

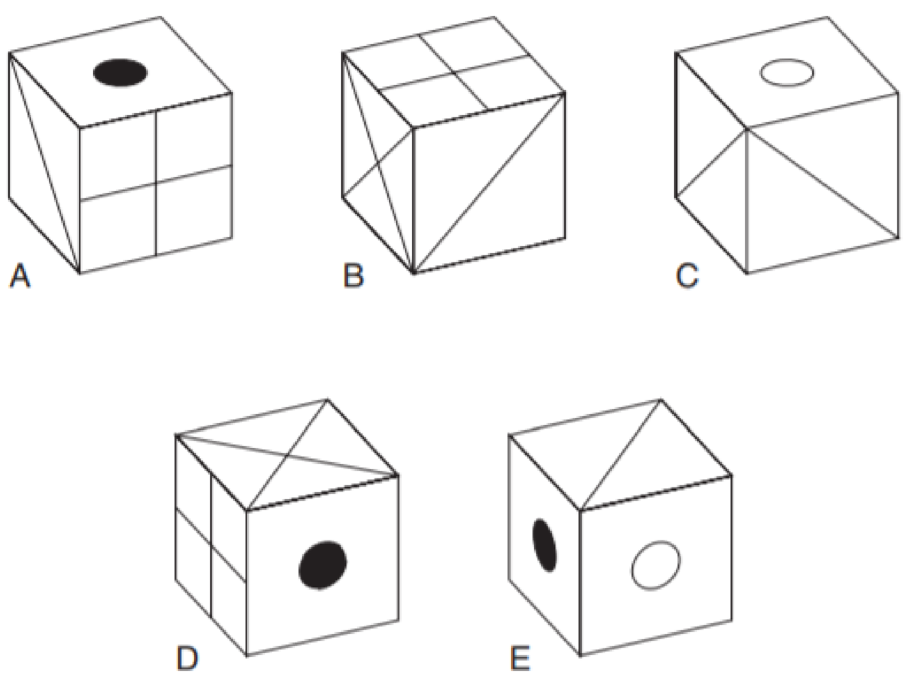


Q12

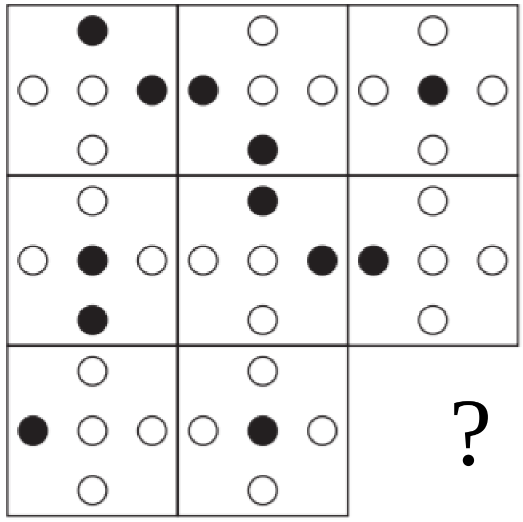


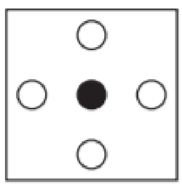
Which cube this shape make?

Bu şekli hangi küp haline getirirsiniz?

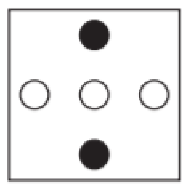


Q13

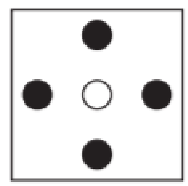




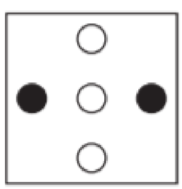
A



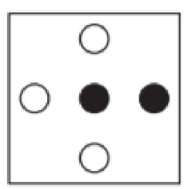
B



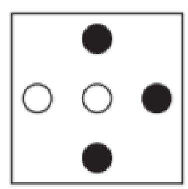
C



D



E

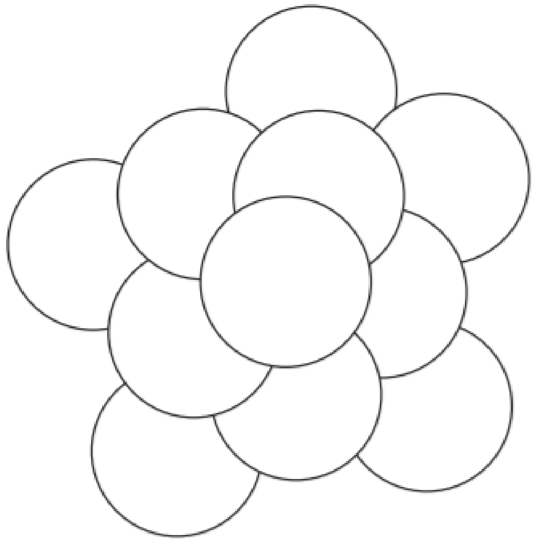


F

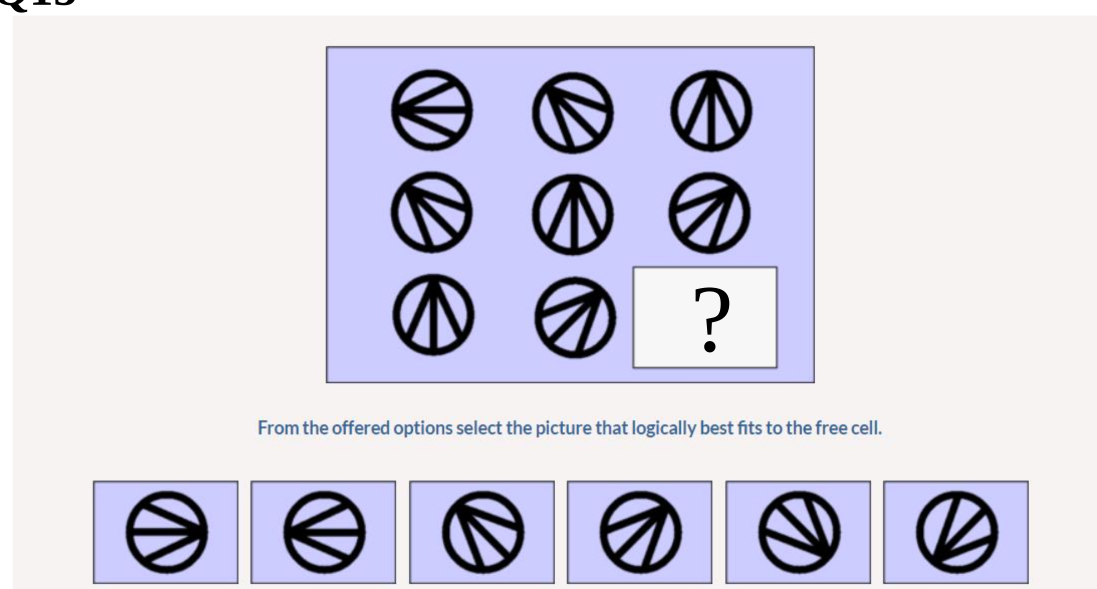
Q14

How many circles?

Kaç tane daire var?



Q15



APPENDIX B

(INDIVIDUAL RESULTS)

ID	Cubicle 1						Cubicle 2					
	Color	Time (mins)	Correct Answers				Color	Time (mins)	Correct Answers			
			Easy	Meduim	Hard	Total			Easy	Meduim	Hard	Total
1	Black	8,75	5	3	3	11	Red	4,83	2	3	5	10
2	Black	12	4	3	1	8	Red	10	3	3	2	8
3	White	7,5	5	2	1	8	Blue	7	4	2	2	8
4	White	8,22	3	3	0	6	Blue	6,13	4	4	3	11
5	Black	9,72	4	2	1	7	Red	6,85	3	2	1	6
6	Black	9,08	4	3	0	7	Red	5,35	3	3	3	9
7	White	9,57	5	0	1	6	Blue	4,67	4	2	2	8
8	White	12	5	4	1	10	Blue	5,2	3	4	1	8
9	White	7,17	5	2	2	9	Blue	4,92	4	3	1	8
10	Black	7,5	4	5	1	10	Red	6,27	3	2	1	6
11	White	10,58	4	4	1	9	Blue	8,57	4	2	4	10
12	Black	8,08	5	3	3	11	Red	7,17	3	2	4	9
13	White	12,75	4	5	2	11	Blue	8,38	3	2	3	8
14	Black	9,8	4	0	0	4	Red	12,02	2	3	2	7
15	White	8,25	4	4	1	9	Blue	6,28	4	2	4	10
16	Black	9,05	3	3	2	8	Red	11,28	4	2	4	10
17	White	7,68	2	3	4	9	Blue	7,17	4	3	4	11
18	Black	8,2	3	1	3	7	Red	7,32	5	3	1	9
19	White	10	5	4	3	12	Blue	9,32	3	3	3	9
20	Black	12,5	4	4	1	9	Red	10,2	4	3	3	10
21	White	8,75	4	4	1	9	Blue	7,05	3	4	2	9
22	Black	8,82	4	3	2	9	Red	9,67	5	2	3	10
23	White	9,35	5	3	1	9	Blue	10,9	3	2	3	8
24	Black	9,3	5	4	4	13	Red	7,63	4	4	2	10
25	White	9,75	4	5	2	11	Blue	10,93	3	3	2	8
26	Black	11,55	4	3	4	11	Blue	11,15	3	4	3	10
27	White	6,2	4	4	3	11	Red	9,67	5	2	3	10
28	Black	11,23	5	2	3	10	Blue	9,68	3	3	2	8
29	White	6,5	5	2	1	8	Red	8,6	3	3	2	8
30	Black	9,5	4	3	4	11	Blue	10,77	5	2	3	10
31	White	5,82	4	4	3	11	Red	7,55	3	3	5	11
32	Black	7,67	4	2	2	8	Blue	8,38	4	4	2	10
33	White	7,18	3	1	2	6	Red	10,18	5	2	2	9
34	Black	8	5	2	1	8	Blue	10	4	3	1	8

ID	Cubicle 1						Cubicle 2					
	Color	Time (mins)	Correct Answers				Color	Time (mins)	Correct Answers			
			Easy	Meduim	Hard	Total			Easy	Meduim	Hard	Total
35	White	6,13	5	4	2	11	Red	9,57	4	2	3	9
36	Black	7,27	5	3	1	9	Blue	7,2	3	3	2	8
37	White	5,27	4	3	2	9	Red	8,35	5	3	5	13
38	Black	14,2	5	3	2	10	Blue	8,25	4	0	0	4
39	White	8,18	5	2	2	9	Red	6,97	3	2	4	9
40	Black	9,37	3	1	3	7	Blue	9,1	4	3	3	10
41	White	9,28	5	4	3	12	Red	10,35	4	2	2	9
42	Black	10,13	5	1	0	6	Blue	5,77	5	3	5	13
43	White	7,63	5	3	2	10	Blue	7,35	4	2	3	9
44	Black	15,7	3	0	2	5	Red	8,1	4	2	3	9
45	White	12,17	5	1	3	9	Red	6,08	4	3	0	7
46	Black	16,45	3	3	2	8	Blue	9,47	4	2	3	9
47	White	8,2	5	1	2	8	Red	7,52	4	2	1	7
48	Black	6,52	5	2	0	7	Blue	7,27	2	2	3	7
49	White	6,17	4	4	2	10	Red	10,5	4	2	5	11
50	Black	12,4	5	4	4	13	Blue	5,85	3	3	3	9