ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

THE CONCEPT OF ILLUSION FROM DESIGN'S PERSPECTIVE: A STUDY ON OPTICAL ILLUSIONS IN PRODUCT DESIGN

M.Sc. THESIS

Sina JAHANGIRI

Department of Industrial Product Design

Industrial Product Design Programme

MAY 2015

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

THE CONCEPT OF ILLUSION FROM DESIGN'S PERSPECTIVE: A STUDY ON OPTICAL ILLUSIONS IN PRODUCT DESIGN

M.Sc. THESIS

Sina JAHANGIRI
(502121912)

Department of Industrial Product Design

Industrial Product Design Programme

Thesis Advisor: Assist. Prof.Dr. F. Pınar Yalçın

MAY 2015

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

TASARIM BAKIŞ AÇISINDAN YANILSAMA KAVRAMI: ÜRÜN TASARIMINDA OPTİK YANILSAMALAR ÜZERİNE BİR ÇALIŞMA

YÜKSEK LİSANS TEZİ

Sina JAHANGIRI
(502121912)

Endüstri Ürünleri Tasarımı Anabilim Dalı

Endüstri Ürünleri Tasarımı Programı

Tez Danışmanı: Yrd.Doç.Dr. F. Pınar Yalçın

MAYIS 2014

Sina JAHANGIRI, a **M.Sc.** student of ITU **Graduate School of Science** 502121912, successfully defended the **thesis** entitled "**THE CONCEPT OF ILLUSION FROM DESIGN'S PERSPECTIVE: A STUDY ON OPTICAL ILLUSIONS IN PRODUCT DESIGN**", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Assist. Prof.Dr. F. Pınar Yalçın** İstanbul Technical University	.....
Jury Members :	**Assoc. Prof. Dr. Çiğdem Kaya** İstanbul Technical University	.....
	Assoc. Prof. Dr. Ahmet Zeki Turan Mimar Sinan University	.....

Date of Submission : **22 April 2014**
Date of Defense : **23 May 2015**

To my fiancé and family,

FOREWORD

I would like to express my deep gratitude to my adviser, Assist. Prof.Dr. F. Pınar Yalçın, who supported me both scientifically and spiritually from the very first until the end of this journey; without her supports this thesis would not be here right now. In addition, I would like to give special thanks to my fiancé, family and friends for their generous understanding and moral support.
Finally, this work is supported by ITU Institute of Science and Technology.

May 2015

Sina JAHANGIRI
(Industrial Designer)

TABLE OF CONTENTS

Page

ABBREVIATIONS

2D	**:** Two Dimension
3D	**:** Three Dimension
BCAA	**:** British Columbia Automobile Association
D65	**:** Daylight 6500 Kelvin
iOS	**:** iPhone Operating System
LED	**:** Light Emitting Diode
Op-Art	**:** Optical Illusion Art
RDS	**:** Random Dot Stereogram
RGB	**:** Red Green Blue

LIST OF FIGURES

Page

THE CONCEPT OF ILLUSION FROM DESIGN'S PERSPECTIVE: A STUDY ON OPTICAL ILLUSIONS IN PRODUCT DESIGN

SUMMARY

The word 'Illusion' can be defined as an effect between what our sensory system receives and what our brain interprets about that phenomenon. People mostly think about illusion as a magic, hobby or a psychological experience but it could have more usage that is important too. The most important application of illusion can be found in nature as camouflage, which can also mean the distinction between life and death. Although, the most known illusion among society is optical illusions, it could occur due all of human senses; as well as, tactile illusion, hearing illusion, smell and taste illusion.

The field of illusion is very popular and attractive since the ancient times and people have always wondered about the perception received from an illusion. Therefore, at the beginning, it has been decided to have a research in the field illusion and design; while, it is been seen that not much studies in design have been done on this topic. after all the concepts that the researcher thought are put out as a mind map it is recognized that the illusion and design is a huge field of study to be fit in a single thesis. Although we have five major senses, but most of the information from our surroundings are received by the eyes, which making the sight an important part of our lives; thus it is purposed to limit the subject of the study to the theme of optical illusion and product design. Generally, this research aims to find the relation between the optical illusion and the product design.

The literature review chapter (second chapter), introduces the nature of optical illusion and discuss the different types of it, which were gathered from books that most of them could be assume as reference books, as well as the most of the recently published research papers, literature and newspaper articles which were found via Internet search to receive the updated data.

The chapter of 'illusion and design' (third chapter) is demonstrating the application of optical illusion in products and other designs. At first, a few examples about usage of illusion illustrated by exemplifying camouflage in nature, some masterpieces in art and a few buildings in architecture to see the other usage of optical illusion. Then in the second part, the field of optical illusion in the industrial design is analyzed by given samples. In this part, a model suggestion is made to classify the relationship between optical illusion and product design; designers may use three techniques to apply optical illusion to their products that include, 'Appropriation of illusion in design', 'Design inspired by illusion' and 'Design creating an illusion'. Designers can create or use illusion in their products to attract consumers and make them satisfied throughout their experience of usage.

The example collection in this study is based on searching the Internet which has been done in two ways; first is directly accessing to the well-known designer and companies' websites and second is using the keywords such as "illusion and product, illusion and design, op-art and etc." in common search engines.

For further studies, the illusion from other senses including, auditory illusion, tactile illusion, tasting and smelling illusion can be a good topic to research not only in product design but also, in the other aspects of design such as safety, packaging, marketing and social design. Besides, more practice based research options can be considered on the same topics by the aid of new generation computer's 3D programs and 3D printers.

TASARIM BAKIŞ AÇISINDAN YANILSAMA KAVRAMI: ÜRÜN TASARIMINDA OPTİK YANILSAMALAR ÜZERİNE BİR ÇALIŞMA

ÖZET

Beş duyu organı ile ortaya çıkan sezgisel güç ve algı arasındaki etki İllüzyon kavramı ile açıklanır. İnsanlar genellikle, illüzyonu bir sihir, hobi veya psikolojik olarak edindikleri tecrübe olarak dile getirirler. Ancak, bu kavramın hayatımıza kattığı anlam ve bütünlük çok daha etkilidir ve çok daha önemli konularda karşımıza çıkabilmektedir. En önemli kullanım alanı, kamuflaj yapabilme imkanı bulabildiğimiz doğal çevredir. Bu doğal çevrede kamuflaj olarak yaratılan illüzyonlar o kadar önemlidir ki ölüm ve yaşam arasındaki ayrıt edici etkiyi ortaya koyarlar. Çevremizde birçok çeşit illüzyonla karşılaşmamız mümkünken insanlar sadece genel olarak görsel illüzyonun farkında olmalarına rağmen her duyu organımıza hitap edebilecek illüzyonlarla karşılaşabiliriz. Örnek verecek olursak; dokunarak, duyarak, kokusu ve tadını alarak farkına varabileceğimiz illüzyonlar da mevcuttur.

Eski çağlardan beri İllüzyon, insanların merakını uyandıran ve ilgisini çeken bir alan olmuştur. Bu sebeple, tarihten beri insanların hayatında önemli bir yer tutan bu konudan yola çıkarak İllüzyon ve Tasarım konuları üzerinde çalışmaya karar verildi. Fakat, daha sonra konunun planlamasına yönelik "zihinsel harita (mind-mapping)" ortaya konulmaya başlandığında, yapılmaya karar verilen bu alanın çok geniş bir perspektife sahip olması nedeniyle, konu sınırlaması yapılmasına karar verildi.

Genel olarak zihinsel harita yöntemi, düşünceleri sınıflandırabilen, problem çözmede araç olarak kullanılabilen ve bilgileri görsel olarak organize edebilen bir yöntemdir. Bu sebeple çalışmamızı, "ürün tasarımı" ve "görsel illüzyon" konuları çerçevesinde sınırlandırdık. Diğer taraftan, bu sınırlamanın bir başka nedeni de, beş duyu organımız içerisinde görsel yeteneğimizin diğer duyu organlarımıza göre algılama gücünün yüksek olmasıdır. Zihinsel harita yöntemi aynı zamanda bölüm başlıklarının belirlenmesinde önemli rol oynamıştır.

Çalışmanın literatür bölümünde öncelikli olarak daha geniş bir perspektiften bakabilmek adına illüzyonun tarihi ele alınmış ve görsel ilüzyonun tanımı yapılmıştır. Konumuzun ana temasının görsel illüzyon olması sebebiyle göz anatomisinin önemi anlaşılmış ve bu alanda açıklamalarda bulunulmuştur. Dolayısıyla gözün anatomisi ve görsel illüzyona sebep olabilecek bileşenleri hakkında bilgilendirmeler yapılmıştır. Daha sonra görsel vizyon ve görsel illüzyon arasındaki ilişkiyi anlamlandıran renkli vizyon, binoküler vizyon, uzaklık ve büyüklük algısı, stereoskopik vizyon ve derinlik algısı ele alınmıştır. Renkli vizyonun açıklaması yapılırken ilk önce renk kavramının tanımı yapılmış ve görüş alanımızı oluşturan dalgaboyundan bahsedilmiştir. Binoküler vizyon, iki gözün kullanımı sağlayan görüş açısıdır ve bu görüş açısı sebebiyle insanın üç boyutlu görebilme yeteğinden bahsedilmiştir. Diğer taraftan, uzaklık ve derinlik algısının

görsel illüzyona nasıl dahil edilebileceğinden bahsedilmiştir. Stereoskopik vizyon ve derinlik algısı başlığı altında üç boyutlu algının televizyon, sinema ve fotoğraf insanlara aktarılmasını gerektiren yöntemler açıklanmıştır. Sonraki aşamada görsel illüzyon çeşitleri ele alınmıştır.

Farklı kaynaklarda illüzyon çeşitlemeleri değişik şekillerde ele alınmakla birlikte, çalışma alanımızın perspektifini oluştururken yararlanılan kaynaklarda ortak olan illüzyonun üç çeşidi dikkate alınmıştır. Bunlar, fizyolojik illüzyon, kavramsal illüzyon, fiziksel illüzyondur.

Fizyolojik illüzyonda adından da anlaşılacağı gibi illüzyonun algı sebebi, insanın sahip olduğu organlardır. Tez çalışmasında da bütün organları kapsamamakla birlikte göz, gözün bileşenleri ve beyin aracılığıyla sağlanan illüzyonlar üzerine odaklanılmıştır. "Renk ve konstrat" ve "After-image illüzyon" kavramları fizyolojik illüzyon olarak ele alınmıştır. Kavramsal illüzyonda, görsel illüzyon ile geçmiş bilgi ve yaşanan tecrübeleri arasındaki ilişkiden bahsedilir. Kavrmasal illüzyon, en az iki algı alanı bulunan ambiguous (belirsiz) illüzyon, sanal ve gerçek arasındaki algıyı anlatan distorting (biçimi bozulmuş) illüzyon, imkansız görsellerle ilgili paradoks illüzyon, birden fazla parçaların birleşimi sonucu var olmayan şekillerin algılanmasına sebep olan fiction (kurgu) illüzyon olarak dört başlık altında incelenmiştir. Fiziksel illüzyon da ise, fiziksel kurallar sebebiyle ortaya çıkan (gökkuşağı ve serap gibi) algısal süreç ele alınmıştır.

Çalışmanın üçüncü bölümü "illüzyon ve tasarım" başlığında ele alınmıştır. Bu başlık içerisinde genel olarak, görsel illüzyonu nasıl ve hangi yöntemlerle kullanabileceğimize değinilmiştir. İlk olarak, doğada görsel illüzyonun, kamuflaj yöntemi ile nasıl kullanılabileceğine değindikten sonra sanatsal eserlerinde ve mimarların bina tasarımlarında kullandıkları görsel illüzyonlara yer verilmiştir. Bu bölümde, ürün tasarımı ve illüzyon arasındaki ilişkiden bahsedilmiş, daha sonra, görsel illüzyonun endüstriyel tasarım içerisindeki yeri ve önemi örneklerle anlatılmaya çalışılmıştır. Henüz illüzyonun ürün tasarımı içerisinde geniş bir yer bulamamasına ragmen, bazı tasarımcılar ürün tasarımlarına illüzyonu dahil etmeye çalışmaktadırlar.

Ele alınan örneklerden yola çıkarak söylenebilir ki; görsel illüzyonu bir ürüne dahil etmek isteyen tasarımcı üç yaklaşım kullanabilir. Birinci yaklaşım (Appropriation of illusion in design), önceden var olan illüzyonu direkt olarak tasarıma dahil etmektir. İkinci yaklaşım (Design inspired by illusion), daha önce yaratılmış bir illüzyon tekniğinden ilham alarak yeni bir ürün tasarlamaktır. Diğer yaklaşım ise (Design creating an illusion); tasarımın kendi başına bir illüzyon olarak ortaya çıkmasıdır. Elde edilen diğer bir sonuç da, tasarımcılar illüzyonlu ürünleri kullanıcıların ilgisini çekmek ve ortaya çıkan illüzyon tekniğinin farkında olan kullanıcıların tecrübesini paylaşmaktır. Bu üç yaklaşıma değinilirken daha önce illüzyon kullanılarak tasarlanan ürünlere yer verilmiş ve analiz edilmiştir.

Tez çalışması yapılırken, görsel illüzyonu bir ürüne dahil etmek için kullanılacak olan üç yaklaşımı test etmek ve aynı zamanda diğer tasarımcıların bu üç yaklaşım ve tez çalışamamı yürütürken sorduğum araştırma soruları (İllüzyon ve Tasarım konulu araştırma neden önemli? Tasarımlar illüzyonu neden tasarımlarına dahil etmektedir? Tasarımcılar illüzyonu nasıl tasarımlarına dahil etmektedirler?) hakkındaki görüşlerini analiz edebilmek için kısa bir antek yapılmıştır. Anket katılımcıları, 23-33 yaş aralığında, Endüstriyel Tasarım ve Mimarlik alanında yüksek lisans ve doktora eğitimi gören 10 öğrenci olarak belirlenmiştir.

Anket, iki bölüm olarak hazırlanmıştır. Birinci bölümde, içersinde illüzyon barındıran ürünler ayrı ayrı 12 adet kart olarak hazırlanmış ve katılımcılardan bu kartları kategorize edilen üç yaklaşım (1. Appropriation of illusion in design, 2. Design inspired by illusion, 3. Design creating an illusion) içerisinde sınıflandırılması istenmiştir. Anketin ikinci bölümünde, katılımcılara cevaplamaları için, ayrı ürünler üzerinden 4 adet soru sorulmuştur. Birinci soruda belirli ürünü hangi yaklaşım içerisinde sınıflandırdıkları, ikinci soruda ürünü neden bu yaklaşım içerisinde kategorize ettikleri, üçüncü soruda tasarımcının ürün üzerindeki illüzyonu neden kullandığı, dördüncü soruda üründe kullanılan illüzyonun negatif ve pozitif yönleri sorulmuştur. Sonuç olarak, katılımcıların cevapları ortak bir tabloda toplanmış ve analiz edilmiştir.

Literatür taraması yaptığımız bölümde, kaynak kitaplardan derlenen görsel illüzyon ve buna bağlı değişik yöntemler anlatılmaktadır. Ayrıca, yeni yayınlanmış araştırma ve gazete makaleleri, güncel bilgi ve görselleri barındırmaları sebebiyle Internet sayfaları kaynak olarak kullanılmıştır.

Çalışma içerisinde yer verilen örnek numuneler, ünlü tasarımcıların ve şirketlerin direkt web sayfalarına girerek alınmış ve çalışmamızla ilgili anahtar kelimeler vasıtasıyla yaygın kullanılan arama motorları sayesinde elde edilmiştir.

Bu çalışama içerisinde İllüzyon konusu “görsel illüzyon” ile sınırlanmış olup, ilerde bu konu üzerine yapılmak istenen çalışmaların da diğer duyu organlarımız ve illüzyon arasındaki ilişki ele alınarak yapılması tavsiye edilmektedir. Diğer taraftan tez çalışmamızda yer verilen ürün tasarımı dışında ambalaj, sosyal ve güvenlik tasarımları gibi çalışma alanları da oluşturulabilir. Ayrıca, teorik temelli yazılan bu tez dışında, pratik yöntemler kullanılarak da araştırmalar yapılabilir ve yeni teknoloji bilgisayar ile 3D programlar bu çalışmalara yardımcı olabilir.

1. INTRODUCTION

The topic of illusion or mind deceiving is very popular and attractive since the ancient times and people have always wondered about the perception received from an illusion. Then, it has been decided to have a research in the field of using illusion in the product design, after studying as an industrial designer; while, it is been seen that not much studies in design have been done on this topic.

Overall, this research is to find the relation between the concept of optical illusion and the product design. Therefore, this chapter briefly explains a background of different types of illusion and expresses the aims and limitations of this research. Afterwards, in the following chapters, the nature and different types of optical illusions will be explain to have a better understanding about it. Then, applications of optical illusion and also the usage of optical illusions in product design are discuss to find the answer for the research questions.

1.1 Background of Study

Illusion is defined as "something that is not really what it seems to be" according to the Cambridge Dictionary; in other words, illusion is an effect between what our sensory system receives and what our brain interprets about that phenomena (Solso, 2008). We mostly think about illusion as a magic, hobby or a psychological experience; for example, two parallel lines, which seem not to be parallel or a still image, which seems to be moving. However, illusions are much important than a moving image, sometimes they can mean the difference between life and death. For example, a tiger's skin pattern plays a role of camouflage to make the tiger invisible and helps it hunt faster and lose less energy. Being inspired by the nature, we also design this kind of camouflage for soldiers' uniforms, separately by use in different environmental conditions of battlefields to keep them unrecognizable from the enemy.

However, illusion is not only about the vision; it contains all of our senses. An auditory illusion is an illusion of hearing. Discussing about most of the auditory illusion needs professional knowledge about physic, frequency, sound and music, but the most famous auditory illusion that we all know is the surround or 3D (three-dimensional) sound, which is used in cinemas and home theaters. As Holman (2008) mentions, it is a group of sound effects that manipulate the sound produced by stereo speakers, surround-sound speakers. This frequently involves the virtual placement of sound sources anywhere in three-dimensional space. This means with the speakers in the front, while, the listener can virtually recognize the voice from behind, left, right and so on.

Illusion of touching is called tactile illusion. Experiences on our nerves and tactile senses demonstrate that everything we feel from our tactile sense may not quietly be the thing we touch. One of these famous experiences is Aristotle illusion; it is so easy to perform, just cross your two middle fingers, close your eyes and touch a small round object like a bean with your crossed fingers, and it feels like you are touching two beans. This also works if you touch your nose (Fiorio, Marotta, Ottaviani, Pozzer, & Tinazzi, 2014).

About illusion in tasting and smelling, these two senses complete each other; for example, if you block your nose you cannot get the taste of the food you eat. We all know the benefit of eating vegetables and other healthy food, but they usually do not have delicious tastes, especially for children who are unwilling to eat them. In this way, a Canadian-based company, Molecule-R, created the Aroma fork, which uses odor to add additional tastes to our favorite dishes. Because so much of taste is based on our sense of odor (which is why food tastes different when we are congested), using odor gives this illusion of taste, despite the fact that you are not ingesting any food. The Aroma fork comes with 21 different aromas, including chocolate, vanilla, banana, butter, coffee and so on. **(Url-1)**

Being cognizant of features of illusion and different types of it, will help designers to have much vivid viewpoint about psychological effects of their designs and maybe it can lead to a new manner or ideas of design. As it mentioned before, sometimes it can mean the difference between life and death.

1.2 Aim of the Study

This study mainly aims to find out and define the relationship between the concept of illusion and product design. Illusion in the field of each of our senses has a huge area to fit in a single thesis, so it focuses mainly on the optical illusion in relation with design. Illusion in design is a new branch of study so besides depending on the written material such as books and articles in this field, we should rely on the samples, observation and the experiences which have been done since now.

1.3 Limitation of the Study

At first, it was decided to do this research about the subject of illusion and design, but after having more studies and making a mind map (Figure 4.1) it was realized that illusion and design is a huge field of study, which could not fit into a single graduate degree thesis. Moreover, although we have five senses, most of the information from our environments are received by the eyes, and making sight a very important part of our lives. Due to these points, it is determined to limit the subject of the thesis to the theme of optical illusion and product design.

2. LITERATURE REVIEW

In this chapter, at first a brief history about illusion and the definition of optical illusion will be expressed for having a background about this phenomenon. Due to the optical illusions, which are perceive by the human eyes, it is important to have a brief outlook about the eye construction and its components, which involve in optical illusions occurrence; therefore, the section will shortly describe the eye anatomy and its dependency with the optical illusion. Since this research is based on the field of optical illusion, the relationship between the vision and the optical illusion will be explain as the essential element of human visual perception. Further part demonstrates the different types of optical illusion besides a few examples for becoming familiar with the perception and formation of each one.

2.1 Brief History of Illusion

The history of illusions was dated to around 450 B.C. when Epicharmus and Protagorus commented about optical illusions. Nevertheless, their opinions about illusion differed; Epicharmus thought that visual illusion was caused by the human sense without paying enough attention and easy for messing up mind. His exact words were "*The mind sees and the mind hears. The rest is blind and deaf.*"(Algom, 1992), while Protagorus believed that optical illusion was caused by the external environment which messed human up; He said "*Man is nothing but a bundle of sensations*"(Weiner, 2003).

About 350 B.C., Aristotle thought that both opinions were partially right; he said "*Our senses can be trusted, but they can be easily fooled*"(Preston, 2010). At 300 B.C., another Greek philosopher, Plato, also expressed his opinion on optical illusion. He believed that the five senses of human were relied on human brain for understanding the external environment and they should be worked together.

Later at 1826, a psychologist, named Johannes Mueller, wrote two books about visual illusion and called it as distortion visual illusion; His exploration on visual illusion was inherited by another psychologist named J.J. Oppelin 1854 and it was so popular at that time that an illusion was made and named as Mueller Lyer illusion (Figure 2.1). In this illusion, Mueller describe an optical illusion with simple shapes. Those three lines have a same length but with the directions of arrows at the end of the lines, the length of each line seems to be different.

Todays, optical illusions can be known as an optical art with many illusionary artists such as Akiyoshi Kitaoka in motion effect art, Julian Beever in 3D (three-dimensional) Art and Yonatan Frimer in distortion effect. Many optical illusion works are created by misleading the visual sense and the perception of images by human. However, the application of optical illusion in practical work is still very limited and restricted in certain fields such as product design, architecture and other professions.

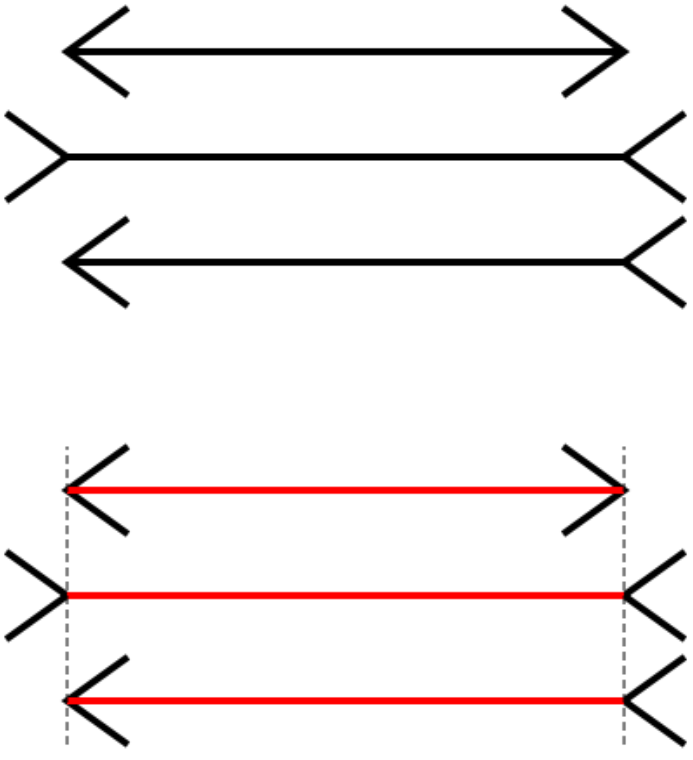


Figure 2.1: Mueller Lyer illusions **(Url-2)**

2.2 Optical Illusion

Optical illusion can also be known as visual illusion. According to the Cambridge Advanced Dictionary, visual illusion can be defined as something that can trick and deceive the human eyes causing them to see things, which are absent or different from the reality.

Visual illusion is an error of visual awareness due to visual mechanism or error of judgment. As Luckiesh (2013) mentions, visual illusion is related to the visual perception and personal judgment of the human being, particularly the sense of sight which is one of the five senses of the human being.

However, people often get confused about the visual illusion and hallucination since both can be classified into the category of misleading perception. With the aim of defining clearly about the difference of these two terms, Luckiesh describes that, "*If two lines appear of equal length and are not, the error in judgment is responsible for what is termed an illusion. If the perceptual consciousness of an object appears although the object is not present, the result is termed as hallucination. For example, if something is seen which does not exist, the essential factors are supplied by imagination*"(Luckiesh, 2013). However, imagination is a source of hallucination and mostly relies on the past experience and the human desire.

2.3 Eye Anatomy

Eyes are important and essential element for visual illusion and the major source for the sense of sight. The most of the information about our environment is gathered by the eyes and its components play an important role on optical illusion`s occurrence; Therefore, the anatomy of eye and its relationship with optical illusion will be explained to understand the reason of the optical illusions` occurrence.

The simple anatomy of the human eye is shown in the Figure 2.2. The eye is a complicated optical system, which contains different components. The major components of eyes include cornea, pupil, iris, lens, retina, fovea, optic nerves (Cassin, 2006).

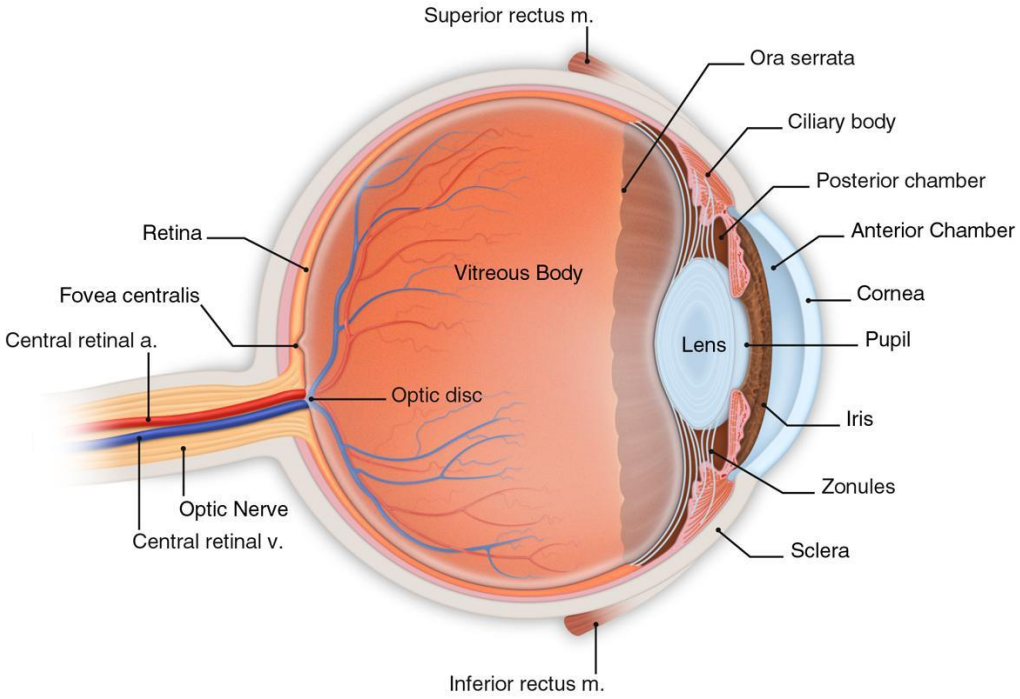


Figure 2.2: The structure of human eye **(Url-3)**

Light enters the eye through the cornea and lens, which focus the picture on the retina. Pupil is a circular area located in the center of the iris. Iris is a colored texture located behind the cornea which can regulate the amount of light which entering the eyes, this is just like how diaphragm regulate the light in the camera.

Fovea is a small hole (about 2mm in diameter) in the macula which produces the sharpest vision due to the possession of high concentration of cones. Optic nerves are largest sensory nerve carrying impulse to the brain. As Solso (2001) mentions, the word retina came from the Latin word “rete” which means “net”; it is named because of the network of blood vessels at the back of the eye. This light sensitive tissue includes rods and cones that can convert the optical image to electrochemical signals, which are the language of the brain.

It will be a surprise to know that our human eyes are not the most complicated optical system in the world. The compound eye of simple arthropods such as insects contains thousands of lenses, whereas we have only two lenses. In general, simple-brained creatures need more complex eyes while complex-brained creatures like human needs less complex optical sensors. Although eye is our best sensual organ, it also has optical issues. Optical illusions would have never happened, if the eyes were

perfect. Indeed occurrence of visual illusion mostly depends on the lens and retina. As discussed by Luckiesh (2013), the defect of the lens returns to the spherical aberration and chromatic aberration.

As shown in Figure 2.3, spherical aberration of lens occurs when the light passed after refraction at large spherical surfaces do not concentrate accurately at the focus (Illingworth & Cullerne, 2009). In fact, visual illusion is thus more likely to occur when the light is focus at different points farther from the axis.

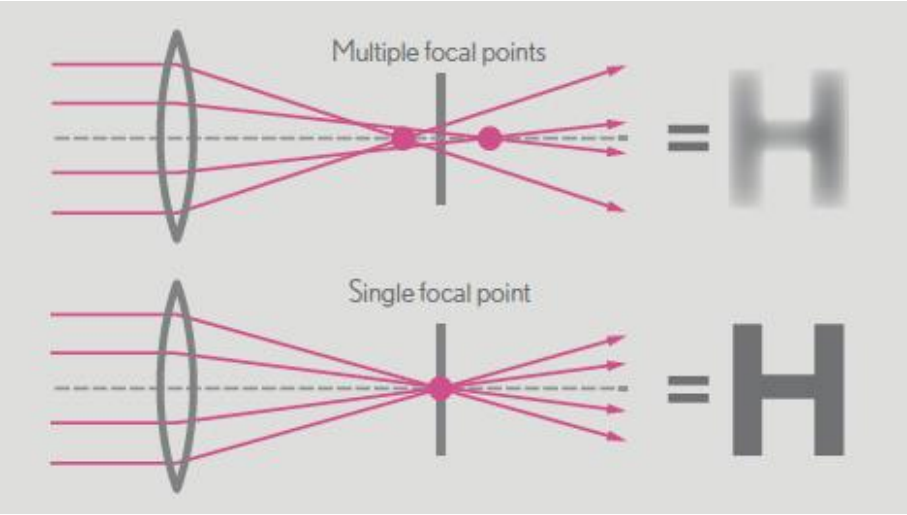


Figure 2.3: Spherical aberration **(Url-4)**

However, spherical aberration can be resolve by paraboloid lens. Chromatic aberration is the distortion of color of an image obtained by the lens which is caused by the variation of refractive-index of different color's frequent. It could be increased by using combination of several lenses that is called achromat lens, which is discovered by Chester Hall in 1729.

As Luckiesh (2013) mentions, white light contains several of light colors which can be separated by a glass prism. As it is shown in the Figure 2.4 the refractive-index of the prism, bent each ray by their color frequency; for example, the red ray with minimum frequency has the least deviation and the violet ray with highest frequency and has the maximum deviation.

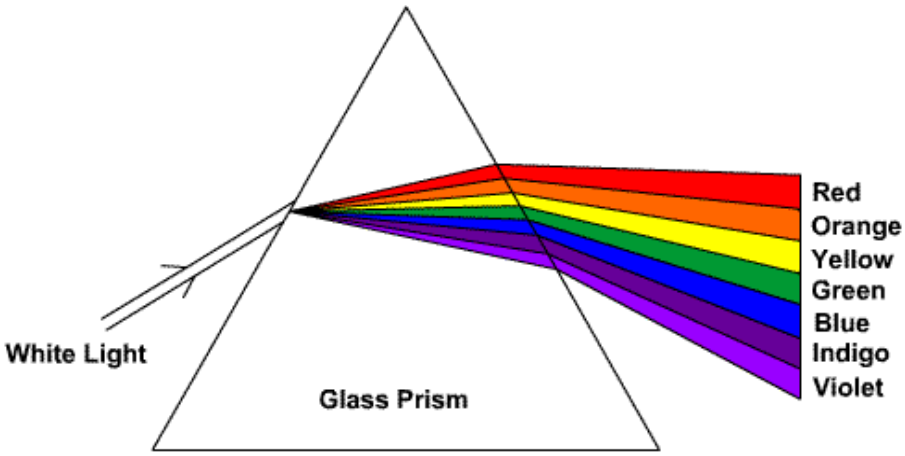


Figure 2.4: Dispersion prism and white light **(Url-5)**

As shown in the Figure 2.5, the lens is quite similar to the prism, thus blue ray focus at a shorter distance and bent more from the straight direction and red ray bent more from the straight direction. Luckiesh (2013) believes that the phenomenon of the chromatic aberration is playing an important role in many illusions which will be discussed later.

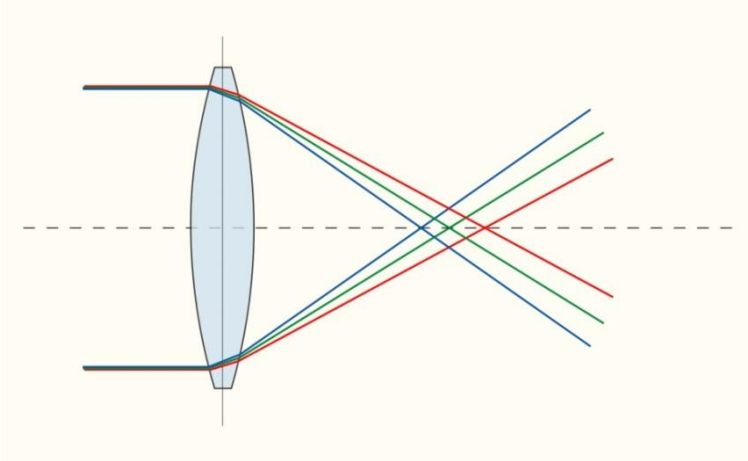


Figure 2.5: Chromatic aberration of lens **(Url-6)**

Discrete from the lens, retina also plays an important role in seeing an illusion, especially the rods and cones. When the light of different frequency is absorbed by these cells, which contain photo-pigments, they perform chemical transformation from eye to the brain. In addition, rods are essential for night vision due to darkness while the cones are responsible for the normal color vision.

However, cognizance of the eye anatomy and the function of each part of it, will lead a better outlook about illusion and its occurrence.

2.4 Vision and Optical Illusion

After understanding the eye anatomy, learning about the vision will give a better perspective about eye and the phenomenon that may cause illusion, such as color, distance and scale perceptions and 3D vision. This chapter will focus on color vision, binocular vision, distance, scale and their relation with the optical illusion.

2.4.1 Color vision

As it is obvious from its name, humans' sight is the essential element in the field of optical illusion. At least three elements are needed in order to have a Vision or see something, include the eye, light and an object with the perception of the brain (Berns, 2002). Every single of them are essential to have a visual perception. So, it is important to expand each element to find out the effect of them on vision.

The first element is light. As Kuehni (2008) describe, light is kind of electromagnetic radiation energy, dividend by the wavelength (wavelength unit is nanometer "nm") in visible light, ultraviolet light, infrared light, radio-wave, micro-wave, x-rays and gamma-rays. As it is shown in the Figure 2.6, the visible light is a small amount between 360 to 780 nm.

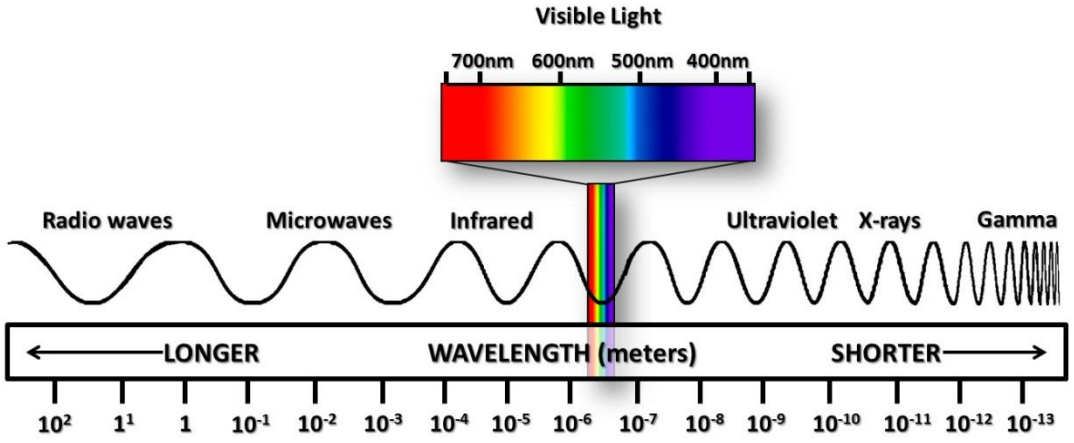


Figure 2.6: Electromagnetic spectrum **(Url-7)**

As McDonald (1997) mentioned, there are two source of light, natural and artificial light. Natural light mostly came from the sun. The direct sunlight is powerful and harmful, but it is reduce by passing through ozone, vapor and particles. The artificial lights are the light of the lamps. Among different kind of lamps, the tungsten lamps

and illuminant D65 have the most naturalist light; they are produce close simulation light to an average daylight. Each light source from natural lights (in different conditions from time to latitude on earth) to various types of artificial lights has a unique value include power, distribution, color and curve which can directly affect the color of objects and cause an optical illusion.

Object is another important component to have a sight. As it discussed by Berns (2002), objects` visibility could be divided into three category in nature; opaque (not able to be seen through), translucent (passes the light but not clear) and transparent (clearly pass the light through). They can result visual cognition by changing the light through transmission, absorption, scattering and reflection.

Transmission usually happened when the object is transparent that with a small amount of reflection allows light to pass through. Absorption happened when an object is colored-transparent then one section of light absorbs by object while other sections reflect, actually the combination of reflecting light composes the color of the object; for example, a green object absorb all spectrum of light expect the green light, so the reflecting color became green. Scattering usually happened on as opaque object, while light hits a different refractive-index surface of an object.

2.4.2 Binocular vision

Binocular vision is the foundation of 3D vision, scale and distance perception; without this ability, human being cannot be able to see many optical illusions such as 3D movies and Autostereogram images. Binocular defined as “the ability to focus both eyes on one object” According to the Cambridge Dictionary. In other words, “"Binocular vision" literally means vision with two eyes, and refers to the special attributes of vision with both eyes open, rather than one eye only. Our perception under binocular conditions represents a highly complex coordination of motor and sensory processes and is markedly different from and more sophisticated than vision with one eye alone”(McCoun & Reeves, 2010). As pointed out by Howard & Rogers (1995) binocular mainly used for depth coding by vertebrate animals which have a substantial area of binocular overlap. As it shown in Figure 2.7 Monocular vision is the area which one eye sees independently, and it is different from binocular area. Human binocular vision angle is about 120 degree while monocular vision of each eye is about 150 degree.

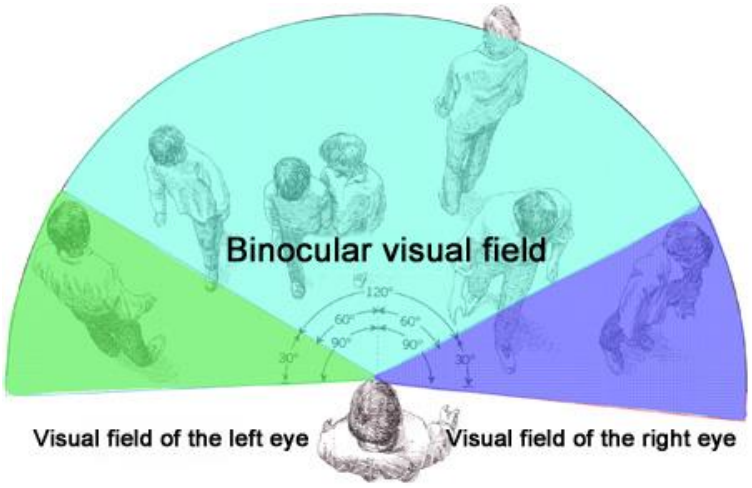


Figure 2.7: Human angle of vision **(Url-8)**

As noted by Walls (1963), only apes and human are developed to converging two eyes and see a bi-fixate image of an object, because of evolution of the eye movement and the close distance of eyes. Other mammals` binocular degree, like cats and dogs are much more reduced. The main reason of the depth of field perception is binocular vision of the human eye. As it shown in the Figure 2.8, the image of the right eye and the image of the left eye, which are occurs in the binocular area combine due brain and the result is the depth perception. Since binocular vision affects the perception in three dimensions of space, it will count as a tool of visual illusion.

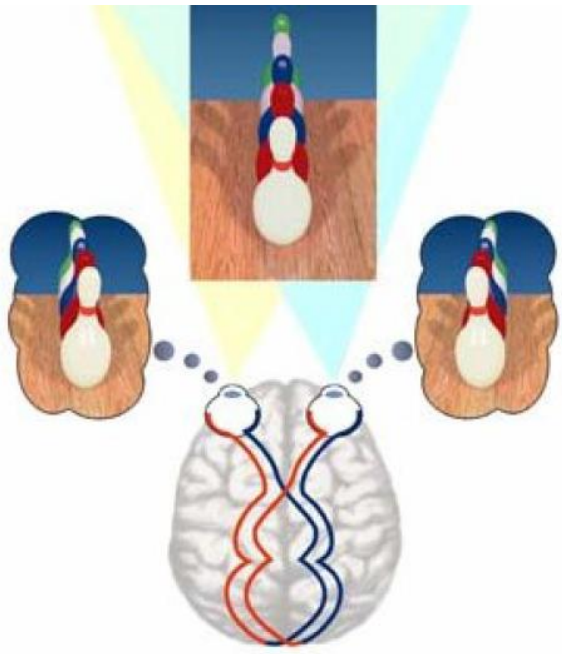


Figure 2.8: Binocular view fusion **(Url-9)**

2.4.3 Distance and scale perception

Distance and scale perceptions are based on both monocular and binocular visions, depend on the object that is in focus. As Luckiesh (2013) described, the perception of distance by monocular focal adjustment and binocular axial adjustment are different and depends on distance, it change from a few centimeters to several meters. The eyes measurement power is fallible, and it could easily fool the perception of measurement. A good example for this phenomenon is 'Ponzo Illusion' as it demonstrates in the Figure 2.9a; it shows three men in the perspective of a street. At the first sight it seems that those three men have different scale from left to right but as it shown in the Figure 2.9b, they are all have a same scale. The perspective of the street and the perception about it mislead human mind. Brain learned that much far objects seems smaller while in this example, three objects have a same size so brain decided that the far one is bigger than the closer object.

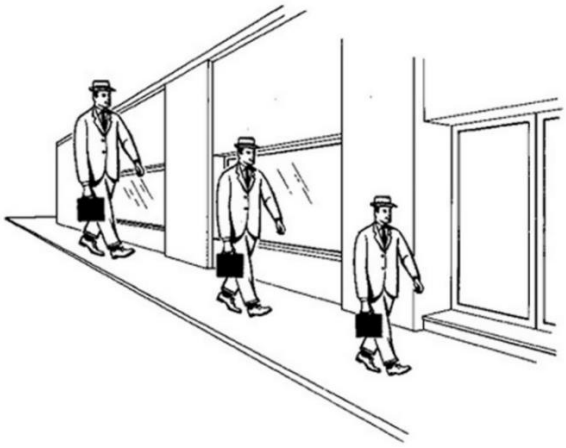


Figure 2.9a: Ponzo Illusion **(Url-10)**

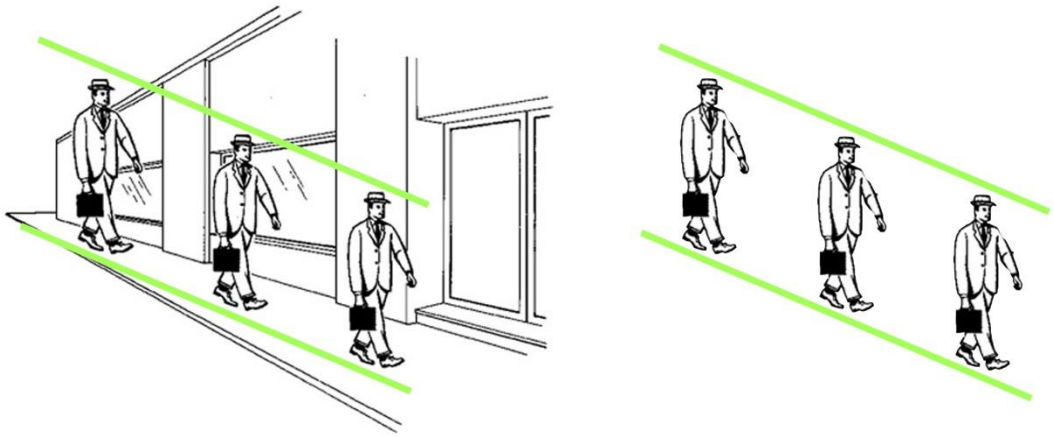


Figure 2.9b: Proof of ponzo illusion, three men have a same size

In the field of distance and scale perception Prinzmetal and Gettleman (1993) have done several experiments to analyze accuracy of monocular and binocular vision on vertical-horizontal perception; the outcome shows that the monocular vision is more accurate while it is less unsymmetrical than binocular vision.

As Luckiesh (2013) noted, the illusion of scale perception is mainly influenced by the illusion of distance perception unless the scales are specific at the beginning; this is well demonstrated in the 'Ames Room Illusion' which the construction is mentioned in the Figure 2.10.

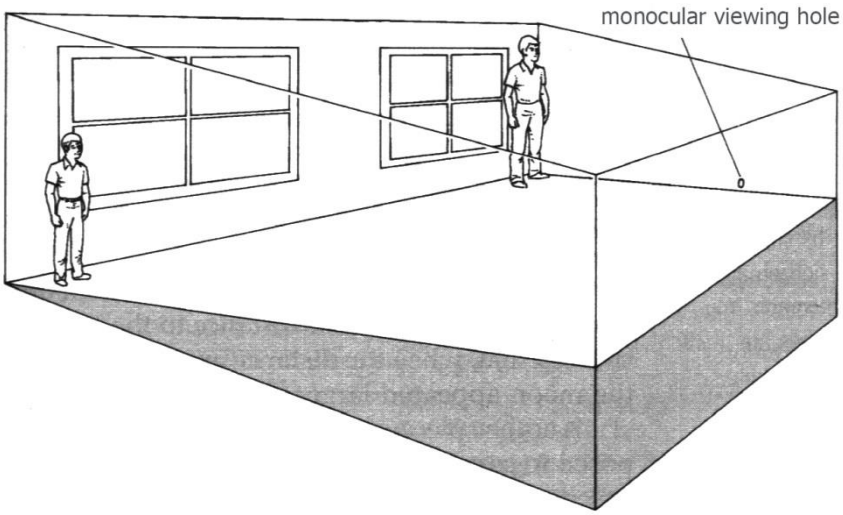


Figure 2.10: Construction of Ames Room Illusion **(Url-11)**

As Harris and Jenkin (2011) explained, the actual shape of the room is a trapezoidal instead of the cube. The man in the left corner is about twice as far as the man on the right side. According to the distance perception, the viewer which looking through the hole, will have the perception that the man who standing in the right corner is bigger than the man on the left side. To conclude, the position of objects to the observer and scale of them may cause the visual illusion.

2.4.4 Stereoscopic vision and depth perception

According to Howard and Rogers (2012), stereoscopic vision could explain as solid sight that leading to the 3D (three dimension) perception which is related to the binocular vision and it is refer to the phrase of 'Stereopsis' which is a Greek word; "stereo" means solid and "psis" means appearance.

An English scientist and inventor called Charles Wheatstone invented the stereoscope at 1838 to inquire the stereopsis; since that time, the research in this field has become so popular. As Luckish (2013) mentioned, Wheatstone's stereoscope which is shown at Figure 2.11, is based on his exploration about the fusion of two images send by eyes, and became the perception of three-dimensional mental image by the brain.

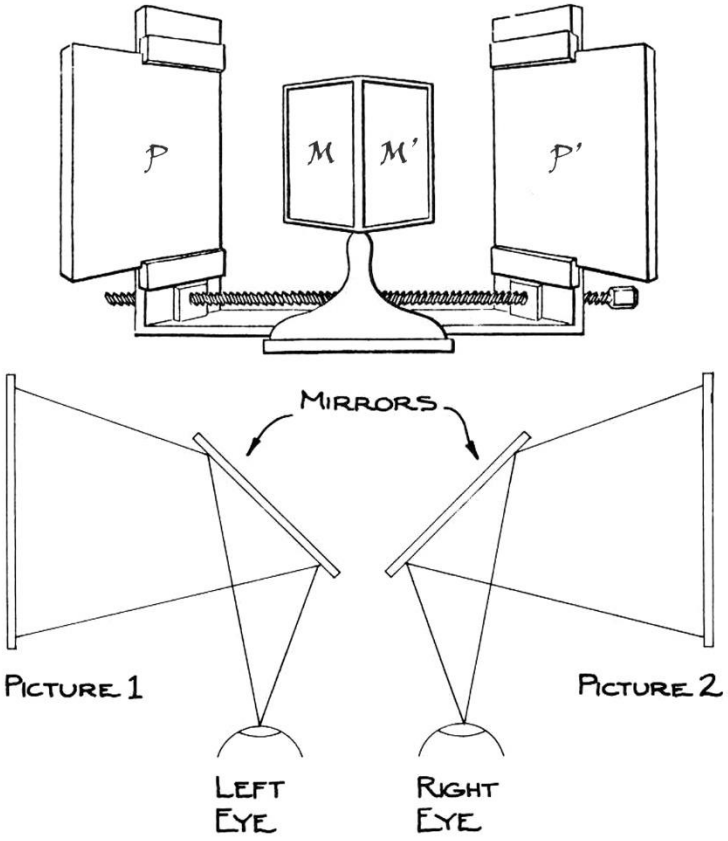


Figure 2.11: Wheatstone's stereoscope and its construction **(Url-12)**

The construction of the stereoscope is very simple; there are two mirrors in the middle (M & M') with 45-degree rotation from the horizon line and two pictures at the sides (P & P') and a Screw to regulation the picture distance from mirror. By looking through mirrors right eye observe the picture 2 and left eye observe the picture 1; and the brain convert the binocular image as a depth perception. Actually those two pictures seem to be similar, but they are not; because the distance of central points of human eyes are about 6 centimeter which means, the image of each eye is little different from the other(see Figure 2.8). Just similar to human eyes the photos, which used in stereoscope machine are taken within about 6 centimeter distance, so they are a little bit different from each other. There is another way to see

the stereoscope depth perception without Wheatstone machine, which called cross-eye technique. Figure 2.12 shows two picture, which could be used by stereoscope, but depth perception, can be seen with naked eyes too. To see this illusion, observers should cross their eyes (like looking at self-nose), and then try to merge to picture to a single binocular image. In this position observer see three pictures, which the right picture came from right eye monocular image, the left picture came from left eye monocular image and the middle picture is the binocular image, which is the combination of two pictures, and cause the depth of field illusion.

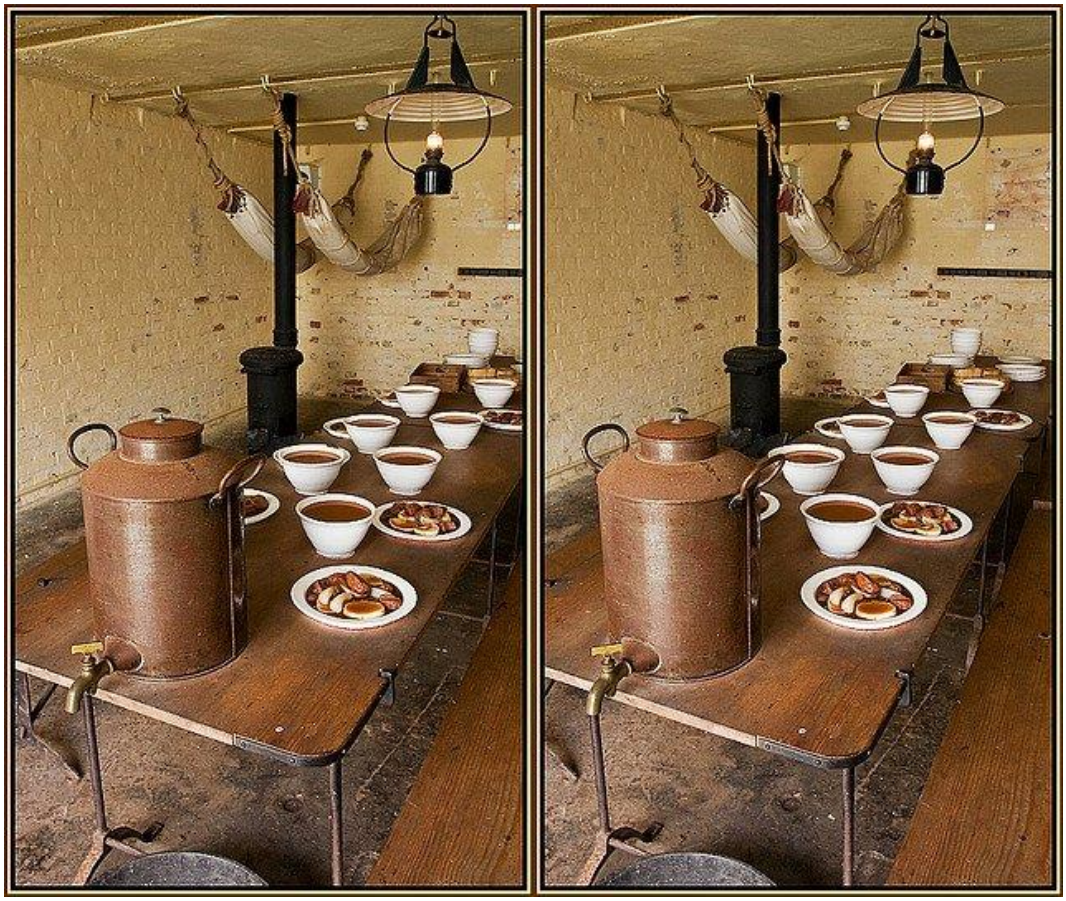


Figure 2.12: A stereoscope image using ross-eye technique **(Url-13)**

Actually, Wheatstone's method is the base to compose today's 3D perception on Stereogram images, cinemas, televisions, cell phones and other devices.

Stereogram as Levine and Priester (2008) describe, is the 3D apperception of depth hidden through 2D image. The first primitive stereogram created by Dr. Bela Julesz in 1959, called Random Dot Stereogram (RDS). It was made from two squares, which are patterned with dots, and there are two smaller squares hidden among the dots in each one of them. When an observer saw them as a stereogram, smaller

square bumped up. Later at 1979, a programmer named Christopher W. Taylor used a program to create first computer-made stereogram, which called Autostereogram.

However, seeing a stereogram is almost similar to the stereoscope images but it is slightly different, the two distinct looking methods called parallel eye (or wide-eye) and cross-eyed vision demonstrates in the Figure 2.13. To see the depth perception in stereoscope observer should use cross-eyed vision while in a stereogram should use parallel vision technique.

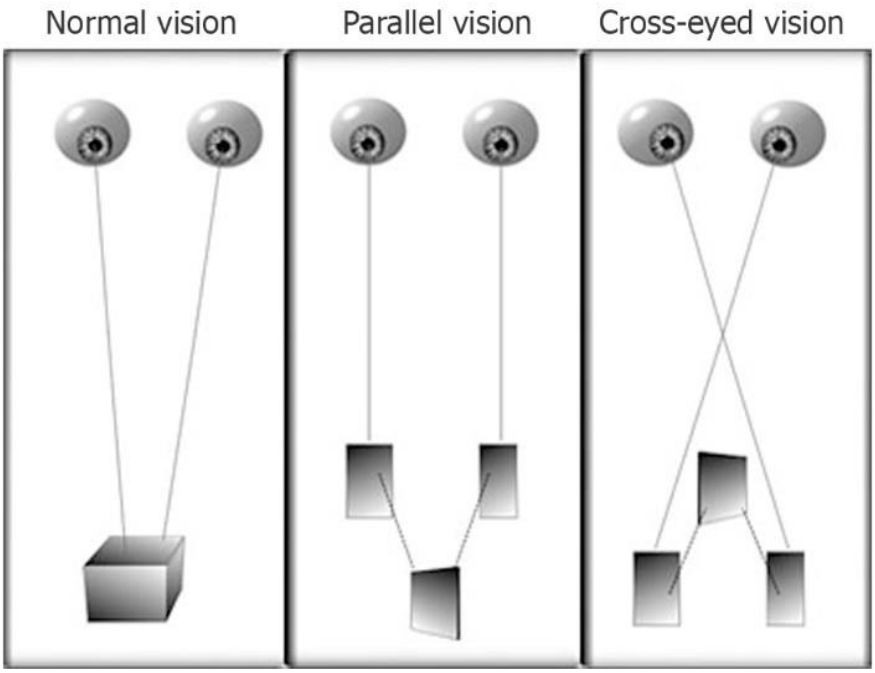


Figure 2.13: Different vision techniques **(Url-14)**

Indeed, autostereogram images could be seen with both cross-eye and parallel eye techniques, but the difference is to see hidden image in convex or concave. By using the cross-eye method, the autostereogram image seems concave, it known as wrong effect; and with the true method (parallel vision) it seems convex. Figure 2.14 display an autostereogram image. It is little tricky to see this kind of illusion, but with a few minutes practice everybody could see it. As Levine & Priester (2008) noted, there are several ways to see an autostereogram image, but the easiest way is to focus at a point about the middle of the picture and relax the eyes, after a while eyes goes slightly unfocused, then the hidden image slowly showed up. For the first times it may take longer to see the image, but after several practices and realization the eye position, it will show up at a snap.

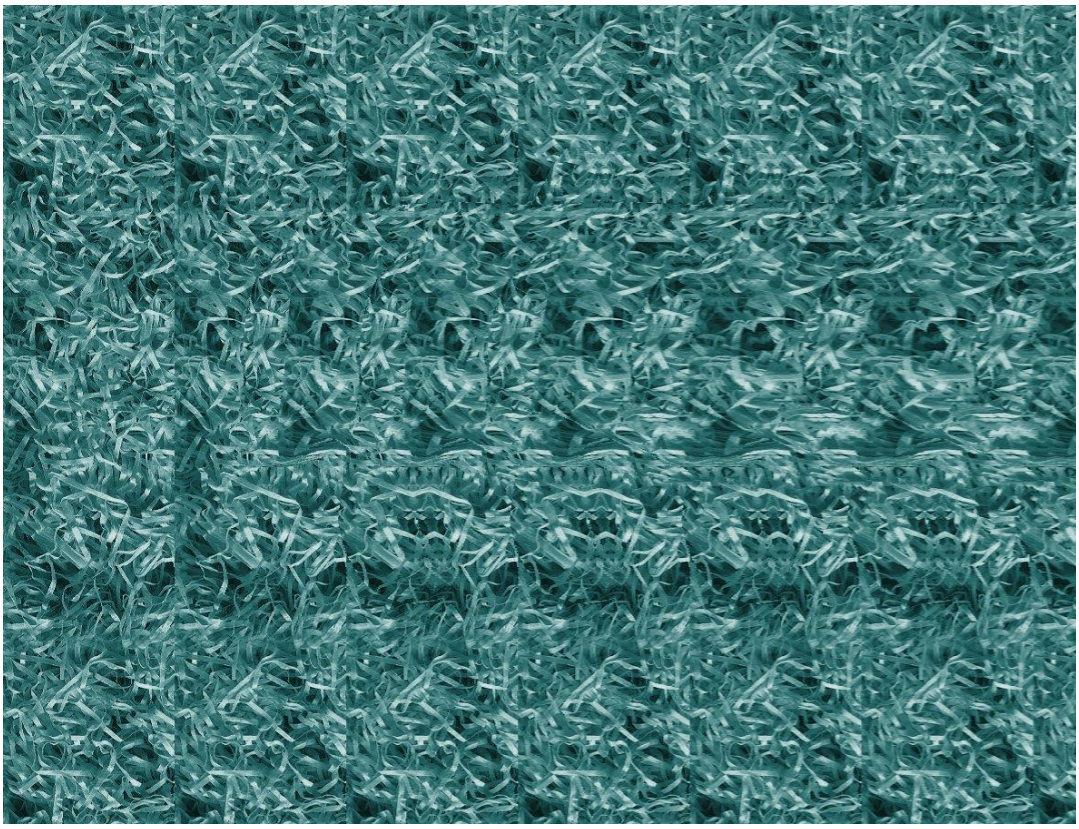


Figure 2.14: Autostereogram image of a dolphin **(Url-15)**

Completely discussing in the field of 3D perception in cinemas and television does not fit in a single thesis, but it will expand briefly at the forward. As it demonstrated before Wheatstone's machine is the base to create other 3D perception like cinemas too. As Fernando, Worrall, and Ekmekcioglu (2013) describes, there are different systems to transfer the 3D sense to viewer. The first red-cyan (or red-green) anaglyph glasses were designed to perceive the effect on blue and red of drawings, in 1852 by Wilhelm Rollmann. Later at 1889, William Friese composed the first 3D animation, used anaglyph glasses. Since that time, the anaglyph glasses used in more movies and get more popular.

The system of deep perception with anaglyph glasses is simple; similar to the stereoscope photography they use two cameras but one lens has been covered by red filter and the other covered by cyan (or green) filter. As it shown in the Figure 2.15, while observers are watching this movie or photograph, the red glasses filter passes just red light, while the cyan filter blocks red and allow blue and green. The overlapping of these pictures in the brain, gives a 3D perception to the viewer.

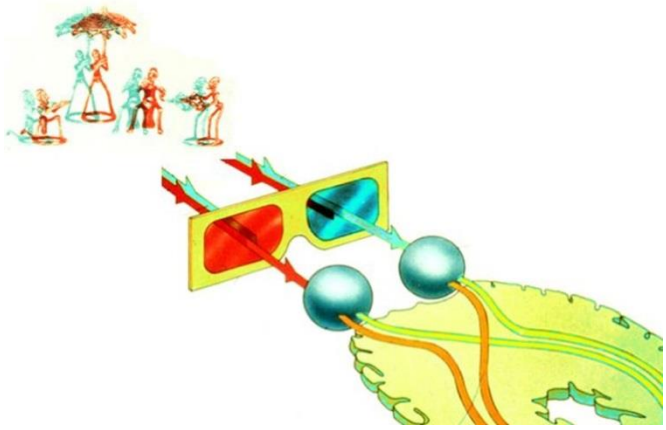


Figure 2.15: Red-cyan anaglyph viewing construction **(Url-16)**

Another device, which creates three-dimension illusion, is polarized 3D glasses. As it is described, lights are electromagnetic waves, which emitted in three-dimension direction. As Bertalmio (2014) mentioned, polarized laminated glass allows one direction to pass and block other wave dimension. As it is illustrated in the Figure 2.16, in the polarized 3D glasses, one glass has vertical polarize filter which allow vertical wave pass through and the other has horizontal polarize filter which allows horizontal wave go across. Same as the stereoscope, recording for the polarized system has been done with two cameras too. At the time when playing the video with two projectors on the screen, one lens is covered with vertical polarized filter to send the vertical rays, while the other lens is sending the horizontal rays. The different pictures received by right and left eyes through polarized glasses, are combined in the brain and give the illusion of 3D perception to the observer.

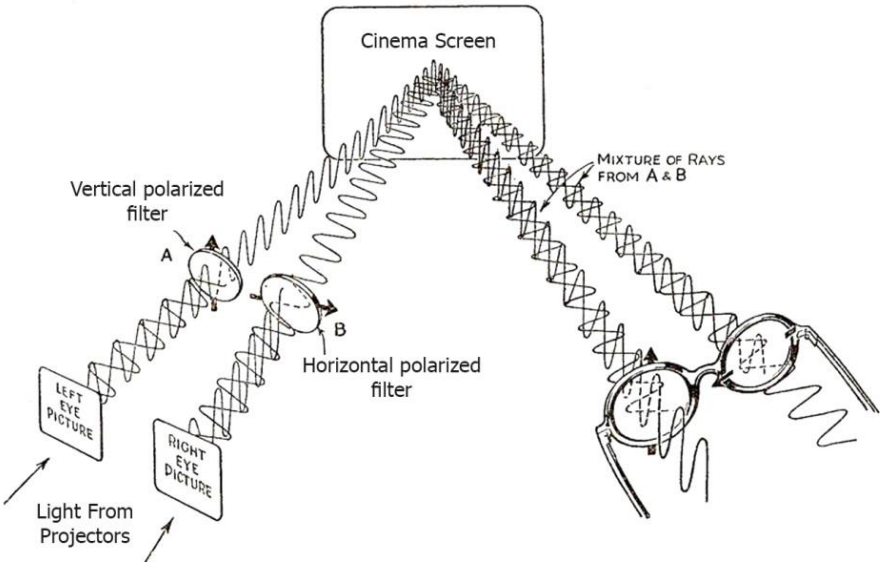


Figure 2.16: Polarized 3D cinema system **(Url-17)**

2.5 Types of Optical Illusions

After having a clear perspective about the human eye, different visions and quiddity of illusion; now, it is time to analyze the different types of traditional optical illusions and their occurrence reasons physically and mentally. However, there is not a certain official classification of the optical illusions; during the researches about optical illusion, it is found out that most of the resources divided the optical illusion into the three main categories including physiological illusion, cognitive illusion and physical illusion and each one of these titles contain subsets, which will be discussed in the following chapters.

2.5.1 Physiological illusion

As Eidenberger (2012) mentions, physiological illusion is the effect of nerves and mind on an individual perception. Indeed, the occurrence of illusion returns to the physiological system of human. Physiological illusion will occur at the time when eyes nerves stimulated with external sources like colors, light, movement and so on. Physiological illusion subsets can be divided into two man category include, color and contrast and after image illusions.

2.5.1.1 Color and contrast

The eyes sensor cells, rods and cones are responsible for the color and contrast illusion. The cones receive colors while rods are sensitive to brightness and highlights. As Ausbourne (2007) describes, most cones are gathered in the center of the retina and most rods are around the edge. Color and contrast illusion occur via this phenomenon while sharp image composed in the center of retina and the blurry image formed around the edge.

As Gregory (2009) pointed, the color we see is not the exact color it is. Colors could be easily influence by their environment colors. A good example for this theory is the ‘checker shadow illusion’ published by Edward H. Adelson, which is shown in the Figure 2.17. The left image demonstrate a checker board with a cylinder; it seems that two square A and B have different tune of grey, but as it shown in the right image, actually both of them have a same color.

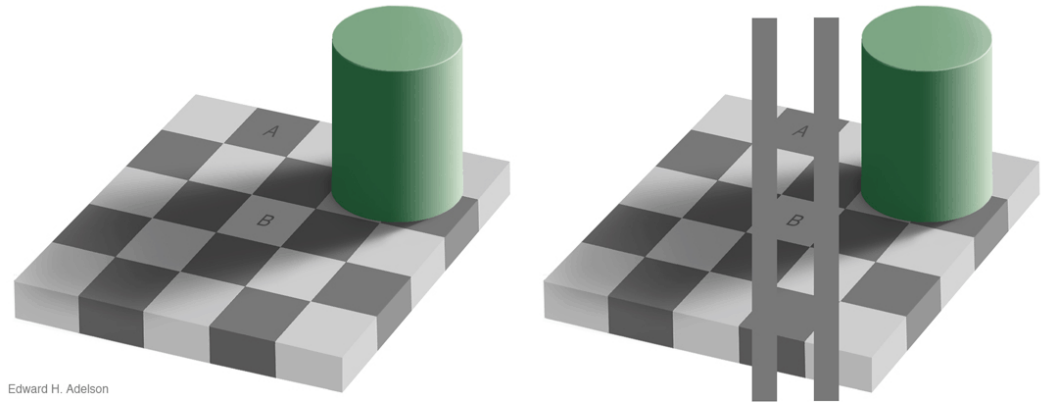


Figure 2.17: Andelson's checker shadow illusion (left), its the proof (right) **(Url_18)**

As Andelson explained himself, in this checkerboard, the cast shadow of the cylinder covers the 'B' square and makes it reflect less light than 'A' square, while human mind turn it to seem lighter. Another reason is, opposite to the 'A', the 'B' square surrounded with dark blocks which make it lighter. These effects increase the contrast between block 'A' to 'B'.

Another theory to proof color and contrast illusion is lateral inhibition, which Eagleman (2001) described, "*We now understand that from the retina onwards, neurons characteristically inhibit or excite their neighbors, depending on their connectivity. This allows the nervous system to enhance contrast between similar regions. Contrast enhancement is generally beneficial, but in some instances generates illusory percepts.*" The Hermann grid illusion at Figure 2.18 is an example of this theory which virtually grey spots are observed at the white intersections and illustrates the color and contrast illusion.

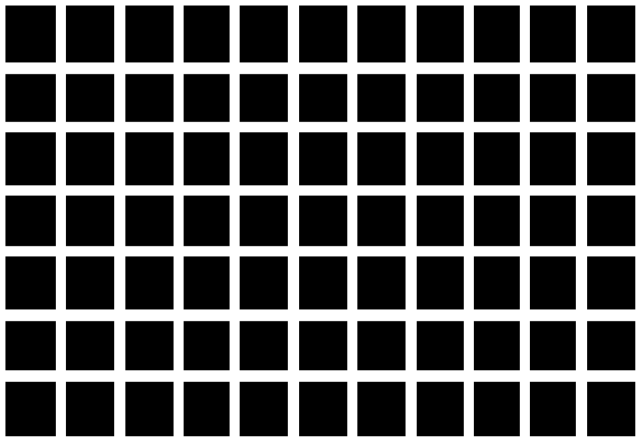


Figure 2.18: The Hermann grid illusion **(Url-19)**

The reason of Hermann grid illusion, as noted by Eagleman (2001), is the competition on stimulation between dark and light sensors in the receptive field of retina. Since a receptor activated, it inhibits the neighboring receptors and causes the illusion.

2.5.1.2 After-image illusion

An after-image illusion is an optical effect of continuing observation of an image, which exposes to the optical system for a certain time. Afterimage perception occurs due the durability or tiredness of human optical system. It is similar to the darkness effect which occur in a shiny snowy day, when you came back to an indoor place; eyes get tired of high level of light in the outside, and it is slowly came back to normal, after getting inside.

As Ausbourne (2007) explains, by staring at an image, the receptors of eyes getting tired or fatigued. After eyes get charged and begin looking at a neutral area, the tired part of receptors does not completely response, in comparison to the fresh receptors, so receptors slowly return back to normal while sending weak signals to the brain; these signals cause the after-image illusion.

Figure 2.19 displays an after-image example; to see the illusion, eyes should focus at the cross sign located in the middle of the image for about 40 to 60 second. Then eyes should immediately drag to a neutral area (for example a white paper or wall) then the illusion of USA flag with the true colors will show up.

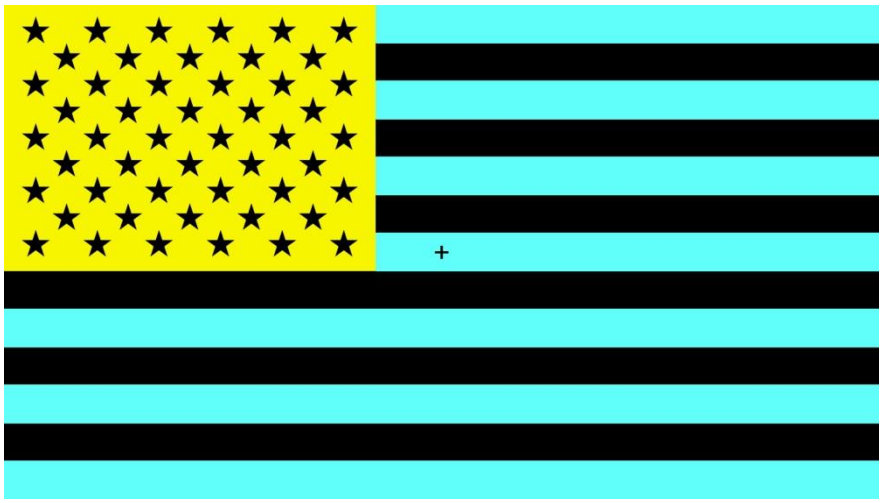


Figure 2.19: After-image illusion of USA flag **(Url-20)**

After-image illusions also include color changings equal to the previous example. To expand this field, having a brief knowledge about additive color combination is essential. Additive color also known as RGB colors, as Saunders (2006) clarified, RGB named after the first letters of Red, Green and blue, which are the primary light colors. It is important to notice that the primary lights colors are different from primary colors (which are red, blue and yellow). As Figure 2.20 illustrates the additive color combination, the mixture of three main colors is white and the other two side-by-side colors as shown are yellow, cyan and purple. As it is seen in the following Figure this additive color chart the opposite colors are pairs of colors which, at the combination, cancel each other, for example blue and yellow are opposite (sum of blue and yellow is white).

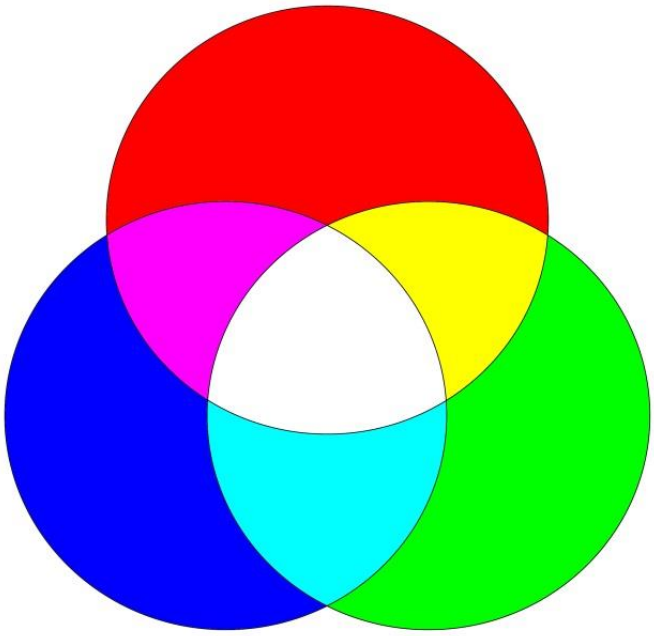


Figure 2.20: Additive color combination of RGB lights **(Url-21)**

However, in the after-image illusion, when human eyes stare at a color, for example yellow, for a certain period of time the receptor cells fatigue from yellow; thus the color that is perceived after looking at a neutral area is white minus yellow, which is the opposite color (in this case it is blue).

According to this theory, the color of USA flag which formerly mentioned in the Figure 2.19, turns into the original colors via after-image illusion because, the opposite colors changes from black to white, cyan to red and yellow to blue.

2.5.2 Cognitive illusion

Cognitive illusion can be defined as a conclusion based on an illusion, which is composed by action and reaction of the optical system and previous knowledge and experiment of the world. For example, the optical system may recognize more than one image in a picture but the brain chooses the most suitable one and it depends on the previous experiences of a person. As Eagleman (2011) mentioned, this hypothesis was discussed by a German physicist named Hermann Helmholtz for the first time in 19th century.

In the following sections, different types of cognitive illusion will be discussed to have better a view about it. Cognitive illusion can be divided into four categories, which are ambiguous illusion, distorting illusion, paradox illusion and fiction illusion.

2.5.2.1 Ambiguous illusion

Ambiguous illusions are pictures or objects, which contain at least two valid interpretations. The images, which are perceived from a specific picture, can be different as observers see it from different angles, perspective or aspect. According to Ausbourne (2007), ambiguous illusions are images which are produced from graphical similarities of optical explanation among two or more different images. Actually, ambiguous illusion causes the phenomenon of the multi-stable perception (also known as multi and stable perception). Two good examples for this phenomenon are Necker cube and Rubin, which will be explained further.

The Necker cube is the most famous example of ambiguous illusion, which is shown in the Figure 2.21. It is a line drawing cube, which was created by Swiss crystallographer, Louis Albert Necker in 1832. Necker cube can be defined as the filliping depth perception, too (Gregory, 2009). Necker cube is a simple wireframe cube which is drawn with the oblique projection perspective. At the instant of looking at the cube, two different perspectives will be perceived by the observer. Figure 2.21a and 2.21b, illustrate two different perspective perceptions of the Necker cube.

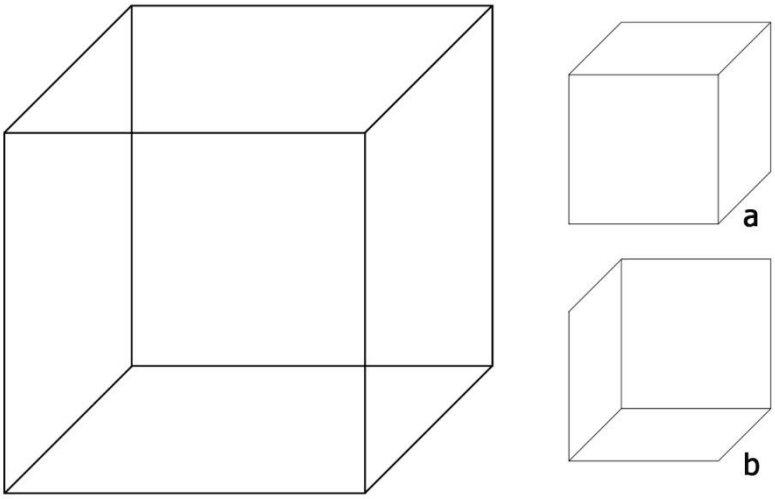


Figure 2.21: Necker cube and two different perspective perceptions (a and b) **(Url-22)**

Rubin vase is another famous ambiguous illusion, which is indicated in the Figure 2.22. This illusion was created by Danish psychologist; Edgar John Rubin, in 1915. Depending on the perception of the viewer this vase can be transform itself to two faces in profile (Darling, 2004). The same effect could happen in a real object with the exact shape of vase and faces. As Gregory (2009) described, this kind of ambiguous are also known as Figure-ground illusion. It is hard to identify the difference between background and Figure because it depends on the observer to decide the white or black color as the ground or faces.

Figure 2.22: From right to left, example of Rubin vase illusion and its 3D vase **(Url-23)**

52.5.2.2 Distorting illusion

As Ausbourne (2007) noticed, the difference among the virtual and the real center of an image caused the distorting illusion. Optical distortion can be divided in to two subsets, which are reception and perception of distortion. Reception of distortion occurs because of disturbed optical sensory signals and the perception of distortion occurs because of misinterpret signals.

However, distorting illusions can be distinguished by the length, size and the flexion of the illusion. A popular distorting illusion sample, known as the "café wall" illusion is shown in the Figure 2.32. This illusion was discovered by Richard L Gregory in 1973 from the tiles of a local café near his laboratory located in the St Michael's Hill, Bristol (Gregory & Heard, 1979). The tiles had chess-like pattern which the vertical borders were not in a same row, but actually all the horizontal lines were parallel. The distorting illusion made the horizontal lines appear not parallel as they are.

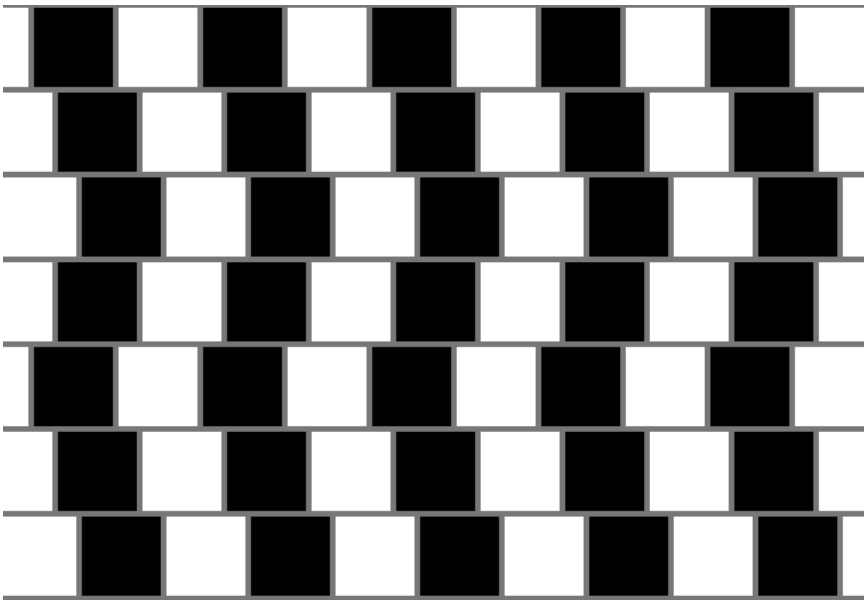


Figure 2.23: Café wall illusion by Gregory, R. 1973 **(Url-24)**

Another example that can fit in the distorting illusion category is Mueller-Lyer illusion, which has been mentioned before in Figure 2.1. It shows three lines with the same length and two arrows at the end of each line; but the observer perceive three different lengths. This illusion happens because of the arrows at the ends; arrows pointing out induce the longer line while arrows pointing inside, inspired the shorter perception.

2.5.2.3 Paradox illusion

Paradox illusions are usually created with impossible or paradoxical images which seem to be correct at the first glance, while they are not following the true perspectives. Paradox illusions mainly occur due to misunderstanding of the connection of faces and edges in an object. So they are mostly presented in a specific view point as two dimensional image to mislead the viewer. Generally their secret will be revealed if the object shown from the different perspectives.

As Ausbourne (2007) noted, the impossible images seemed normal at the first glance, but it was unacceptable from the physical viewpoint; the longer observer looked at this illusion, the more unbalanced features appeared.

"Penrose Stairs" is an example of the paradox illusion, which can be observed in the Figure 2.24. This illusion designed by Lionel Penrose and his Roger Penrose is counted as an impossible object (PENROSE & PENROSE, 1958). This illusion demonstrates a cube-like shape staircase that rotates and gets higher counterclockwise in a loop. Thus, gives the perception that a person could walk up or down on these stairs forever. It is obvious that this is impossible in the real world.

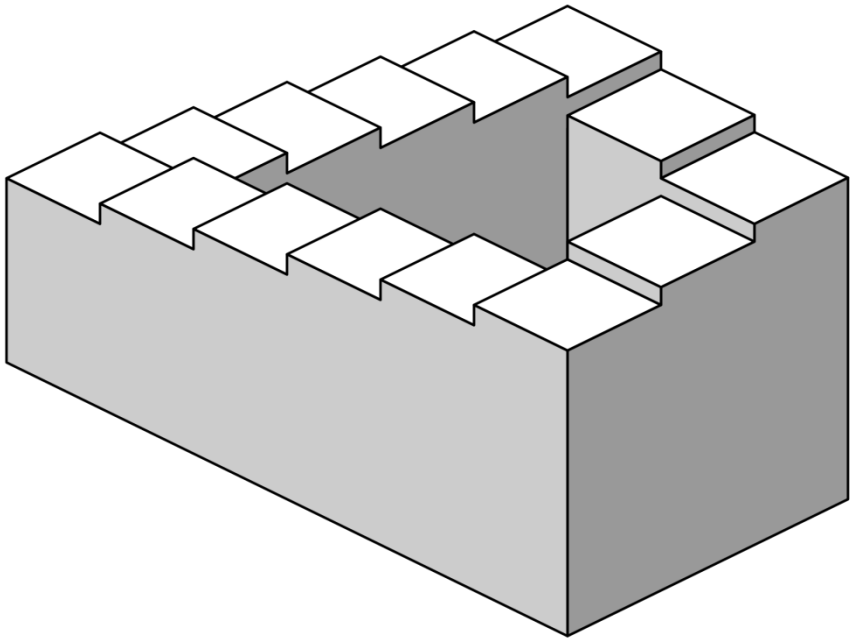


Figure 2.24: Penrose stairs illusion **(Url-25)**

One on the most famous paradox illusion artist was Maurits Cornelis Escher (1898-1972). Different kinds of illusions can be noticed in his all art-works, but one of his well-known works in the field of paradox illusion is called “waterfall” which is shown in the Figure 2.25. In this illusion he creates an endless water canal, due to combining the floor levels in the perspective technique.

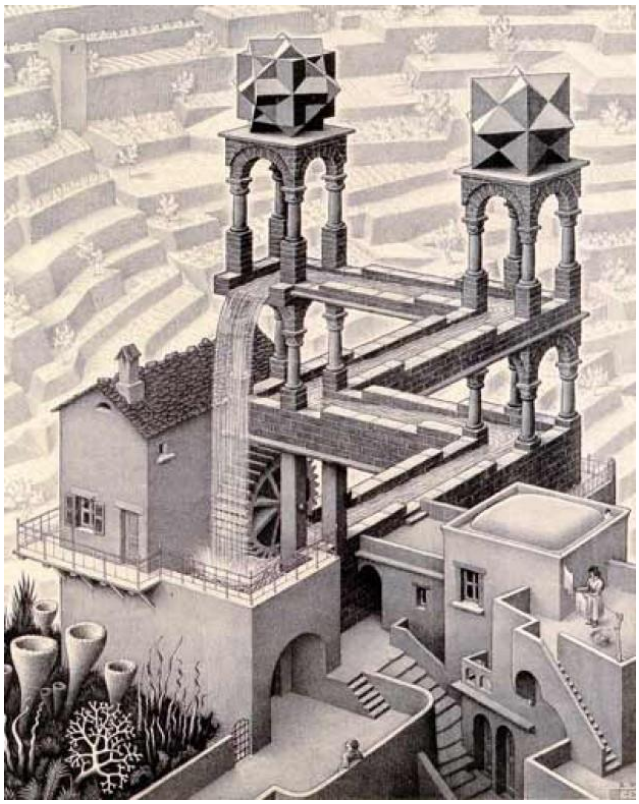


Figure 2.25: Waterfall by M. C. Escher **(Url-26)**

2.5.2.4 Fiction illusion

Another aspect of cognitive illusion is Fiction; it also known as Gestalt illusion. According to oxford dictionary “gestalt” is an German word which mean, ‘form’ and ‘shape’ and also could be defined as “*An organized whole that is perceived as more than the sum of its parts*” Gregory (2009). Fiction illusion can be praised as inducting a shape under the layers of others while it is absence. It means that the fiction illusion is the perception of a non- existing shape or object. A good example for fiction illusion is “Necker Cube” which is displayed in the Figure 2.26. This image contains eight black circles where each one is sliced into several pieces and through these circles a nonexistent cube is perceived. The brain gets used to recognize familiar shapes and has a tendency to make an assembled image from diffused elements.

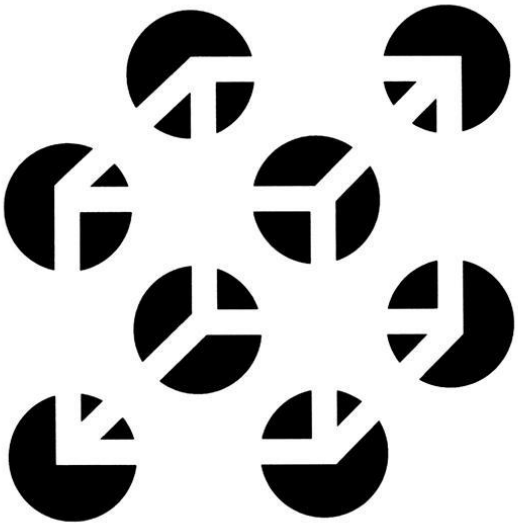


Figure 2.26: Necker Cube shows a nonexistent cube **(Url-27)**

2.5.3 Physical illusion

Physical illusions, as it clear from its name, are the type of illusions, which refer to the physical sciences. Physical illusion is a kind of optical illusion and it used in the opposite of the physiological illusion. As Nicholas (2008) describes, generally physical illusion occurs outside of the brain while the environment and the physics play important roles in this event.

A famous example of physical illusions that everyone might have seen is the rainbow. It usually occurs as the sun shows up after it stops raining, at the time which tiny particles of water are still floating in the air, they act such as a huge prism while the white light of the sun passing through them, disintegrates to the spectrum of various colors (described at the chapter 2.3) which is called the rainbow.

Another good example, which can be explained in this field is the mirage phenomenon. Mirage itself has different types, but two most well-known subsets can be Figured as ‘Inferior mirage’ and ‘Fata Morgana mirage’.

Inferior mirage as it shown in the Figure 2.27, is the surface reflection of the road or desert in the hot weather, which perceive the water or wetness illusion to the observer from far distance. This illusion is caused by a heat layer from the land’s surface staying under a layer of cold air while hot air is rising and cold air is sinking.

And the result bends the light and causes the light reflection of the surface and the inferior illusion (Nicholas, 2008).

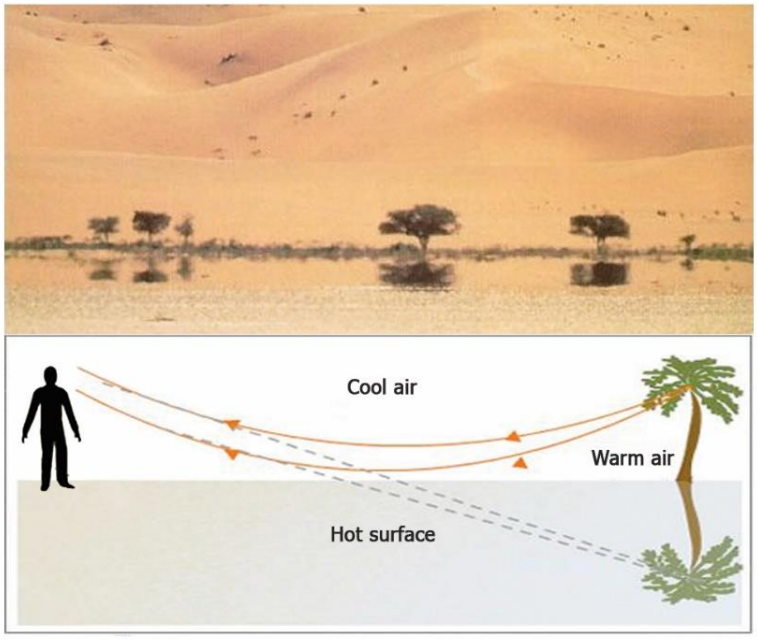


Figure 2.27: Sample of an Inferior Mirage and its scheme **(Url-28)**

Another wired type of mirage is Fata Morgana mirage. The Fata Morgana is named after the legendary 'Morgan le Fay', the enchantress sister of King Arthur. She learned atmospheric magic from Merlin the magician. Her namesake mirage, found over the Strait of Messina, is the "Fata Morgana" (Schwab, 2005). It is a complex mirage, but similar to the inferior mirage while it happens in the opposite way. Fata Morgana mirage usually happens in the oceans while weather is so cold and makes the floating objects (like ships and ice-rocks) seem to be suspending in the air but the illusion shapes rapidly changing. As it demonstrate in the Figure 2.28, Fata Morgana mirage occurs while the surface of the ocean water gets colder than the air above it and another warmer layer of air lying on previous; this layers of airs and the surface are also called layer cake of temperature (Schwab, 2005). Temperature interaction between each layers while light passing through them, diverting the light, coming from the object and perceive the object is hanged in the air ,but the position of it rapidly changed between four different forms which mentioned in the layout of Figure 2.28. It is also good to know that scientists believe that the Titanic disaster and rescue attempts are related to the fata morgana mirage (Broad, 2012).

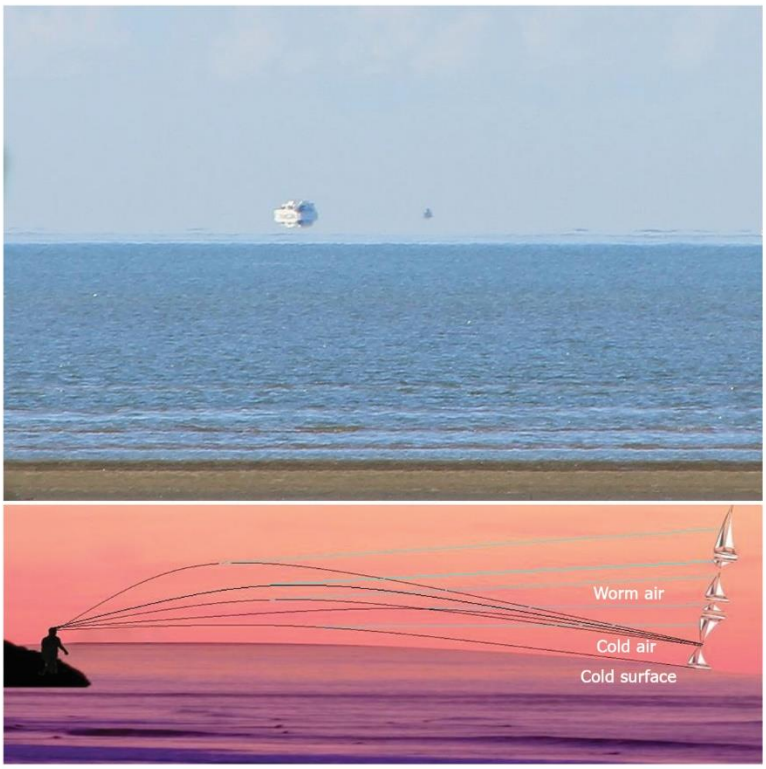


Figure 2.28: Sample of a Fata Morgana Mirage and its layout **(Url-29)**

2.6 Chapter Summary

The first section of this chapter notices the definition of optical illusion and gives a brief history of illusion. The studies of illusion goes back to around 450 B.C. then as the time pass various psychologists, physiologists, scientists and artists bring different theories and illusion until now this process still continues.

Optical illusion also known as visual illusion can be defined as an error of visual awareness due to visual mechanism or errors of judgment. Eyes are important and essential element for visual illusion and the major source for the sense of sight. Although we have five major senses, most of the information from our surroundings comes from the eyes, making sight a very important part of our lives. The major components of eyes described as cornea, pupil, iris, lens, retina, fovea, optic nerves and their responsibilities which each one have been analyzed before.

Three elements are essential in order to seeing things which are light, eye and brain to process the image. Different types of light from visible lights to radio waves and their effect on objects have been described. In the vision categories, we learned about monocular and binocular vision, which are the angle of vision of one eye and both

eye overlapping. Then we are taking about the distance and scale perception while they are explained via two illusion and their effects on human perception. After that, stereoscopic vision and the depth observation noted and different technique of 3D vision are presented with their samples.

In the next section, classification of optical illusion is done as physiological, cognitive and physical illusions. Physiological illusion defined as the effect of nerves and mind on an individual perception, which includes color and contrast and after-image illusion. In addition, cognitive illusion is characterized as a conclusion based on illusion which composed by action and reaction of the optical system and previous knowledge and experiment of the world. Ambiguous illusion, distorting illusion, paradox illusion and fiction illusion are explained as subsets of cognitive illusion. Then the physical illusion is defined as a type of illusion, which occurs outside of the brain while the environment and the physics play important roles on it. Then rainbow and mirage are expanded as a physical illusion to have a better view about it.

To conclude, this chapter tries to make the definition of different types of optical illusion and its relation with the eye and the brain and occurrence of illusions to have a vivid background about the matter of optical illusion and the effects of them on misleading the human mind.

3. ILLUSION AND DESIGN

3.1 Introduction

Until now, the different types of illusion have been discussed in order to have the knowledge about the quiddity and the occurrence of these terms. This chapter will illustrate the application of illusion. For having a better outlook, the subject is divided into categories as illusion and design and the application of illusion in other fields, which are nature, art and architecture. In the first part, the application of illusion in the nature will be described with a few samples to realize the oldest usage of illusion. In the following part we will see how artists use illusion to create their artwork. In the further section a few examples of using illusion in architecture will be demonstrated for getting closer to the idea of application of illusion. In the final part, the usage of illusion in the product design will be explained. To have a better analysis, this section separately dissects the application of illusion in three subsets which are, ‘Appropriation of illusion in design’, ‘Design inspired by illusion’ and ‘Design creating an illusion’ within the intention of grasping why and how designers use illusion in their designs.

3.2 Application of Illusion in Other Fields

In this section, some different usage of illusion will be discussed. However, the profession of illusion can be considered as a new field, there are also a few historical and old examples. The oldest usage of illusion refers to the mother of nature. The same clue can be chased in art as well as in architecture too. These applications will be expand and analyze to have a further outlook about how illusion can be useful in such fields.

3.2.1 Illusion in nature

Nature is the oldest phenomenon that human kind may know. Everything in nature has been changing into the most complete and efficient form of it due to the evolution in millions of years. There are so many different types of illusion in nature, some are the illusion itself (like rainbow and other physical illusions which explained in chapter 2.5.3), and some of them are used by nature.

One of the most important applications of illusion in nature is the concept of camouflage. It means the difference between life and death to many animals and plants. Camouflage can be defined as equalization of the outfit to the environment to deceive the enemy (Luckiesh, 2013). Camouflage in nature usually occurs to reach to main purposes; to hunt better in the cover of environment and to not get hunted by the other animals.

As Stuartfox, Whiting, & Moussalli (2006) described, one of the most magnificent types of camouflage in nature belongs to the chameleon which is shown in the Figure 3.1. It belongs to the lizard family that has a special power to change the skin color to mimic the different conditional environments to answer both safety and hunting needs.

Figure 3.1: A chameleon hiding through leaves **(Url-30)**

Although not all animals have the power of changing their colors suddenly, as chameleon do but they sync themselves to the ecosystem via millions of years` evolution. An interesting example of this type of camouflage is Mantodea which also known as Praying Mantis. There are thousands types and colors of praying mantis around the world which are adapted to the environment they live in (Prete, 1999). It can be said that they are the masters of synchronizing; not only in the color changing, but also in the field of shape changing. Figure 3.2 demonstrate two type of mantis, which camouflaged with their environment.

Figure 3.2: Two different types of mantis camouflage **(Url-31)**

It is good to know that color changing is not the only illusion which both chameleons and mantises use to hide; also their movements can be counted as illusion too. Both of them move slowly as they walk, it means too slow for being recognized by the hunt and hunter, but actually they are too fast at the moment of attack.

3.2.2 Art and illusion

The art work in the application of optical illusion can be given as an uncertain delight while it can confuse and mislead the observer (Delvaux, 2013).

A painting technique called ‘Trompe-l'œil’ is a realistic simulation to create an optical illusion to perceive three-dimensional objects. Trompe-l'œil is a French word that can be define as “a painting that is cleverly designed to trick people into thinking that the objects represented in it are really there.” according to the Cambridge Dictionaries online. A good example in this technique is ‘Escaping criticism’ by Pere Borrell del Caso (1835–1910) which is illustrated in the Figure 3.3.

Figure 3.3: Escaping criticism by Pere Borrell del Caso (1835–1910) **(Url-32)**

Todays, optical illusion art (op-art) developed in various branches which all of them can not being fit in this thesis, but one of the famous illusion can be named as ‘Rotating Snakes’ by Akiyoshi Kitaoka in 2003 which is shown in the Figure 3.4.

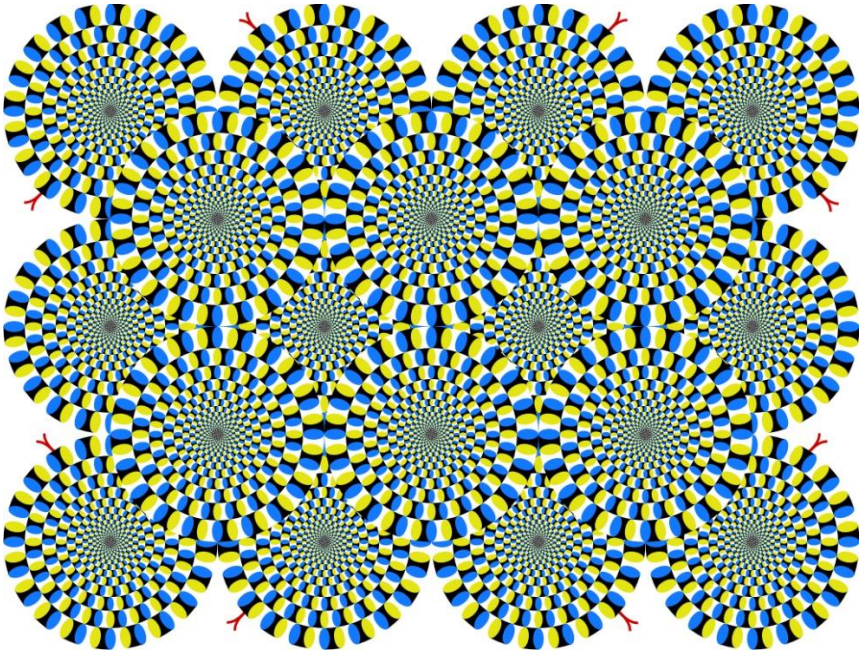


Figure 3.4: Rotating snakes by Akiyoshi Kitaoka **(Url-33)**

This is a static image but it seems to moving since looking at it. Rotation of these circle refer to the color combination of it. Actually eyes follow colors from black to blue, to white and to yellow when these colors repeat continuously, motion perception occurs (Kuriki, Ashida, Murakami, & Kitaoka, 2010).

Julian Beever is another famous British op-artist, which his two dimension paintings on the ground that seem like three dimensional from a certain viewpoint. His art works are usually located on the public floors and drawn with chalk. His technique is called Anamorphosis which is a deformed perspective. One of his works mentioned in the Figure 3.5 are shown from the correct and opposite viewpoints.

Figure 3.5: One of Julian Beever art works in two different viewpoints **(Url-34)**

The previous examples are examples of art, but how could they be useful? A Canadian, British Columbia-based safety awareness group designs and developed the image with the support of the BCAA (British Columbia Automobile Association) Traffic Safety Foundation, the District of West Vancouver, School District #45 West Vancouver, and the West Vancouver Police. As shown in the Figure 3.6, it is an anamorphosis image (distorted projection or perspective images which a specific viewpoint or tool needs to see the correct image) of a child and places it on the roadway near a school to mislead drivers and make them reduce their speed during their drive. As described by David Dunne, Director of the Traffic Safety Foundation, "This is a way to reinvigorate what becomes a pretty tired message every year. We become anesthetized to the risks related to driving, but the risks are very real, especially in British Columbia, where we have more than 400 fatalities each year related to motor vehicles" (CNN, 2010).

Figure 3.6: An anamorphosis image from two different viewpoints **(Url_35)**

3.2.3 Architecture and illusion

Architecture is another field which the application of optical illusion has been applied. Geometrical optical illusion has been obvious in the ancient Greece architecture. As noted by Luckiesh (2013), optical illusion can be seen in the Parthenon temple (demonstrated at Figure 3.7), one of the most famous building from ancient Greece. The stylobate (a continuous base supporting a row of columns) of the building has an upward curve on the sides which is 4 inches higher in the middle than the corners. Also Corner columns are about 2 inches thicker than the others columns and all columns lean inward to the center by about 2 inches. There is no universal agreement about the illusion it gives but it seems that designer add these details to perceive the temple bigger than it is.

Figure 3.7: Parthenon temple and the curves diagram **(Url-36)**

In recent years, the usage of optical illusion in buildings becomes more popular among architects. One of the famous contemporary buildings named as Port 1010 building, located in Melbourne, Australia which illustrated in the Figure 3.8 may be such an example. The illusion that is used for decorating this building is café wall illusion, which explained in the section 2.5.2.2 (distorting illusion). The glass panels are actually parallel, but the special combination of them and the red lines between them make a strange unparalleled perception.

Figure 3.8: Port 1010 building, Melbourne, Australia **(Url-37)**

In addition to this, it is good to know that, by getting inspired from Escher's illusion works (which pointed in the chapter 2.5.2.3 Paradox illusion) an American based digital product studio named 'Ustwo' designed an iOS and Android game in March 2014, called 'MONUMENT VALLEY' which a screen-shot of it shown in the Figure 3.9. In this game player should manipulate examples of impossible architecture and guide a princess to find her way out through a weird illusion world.

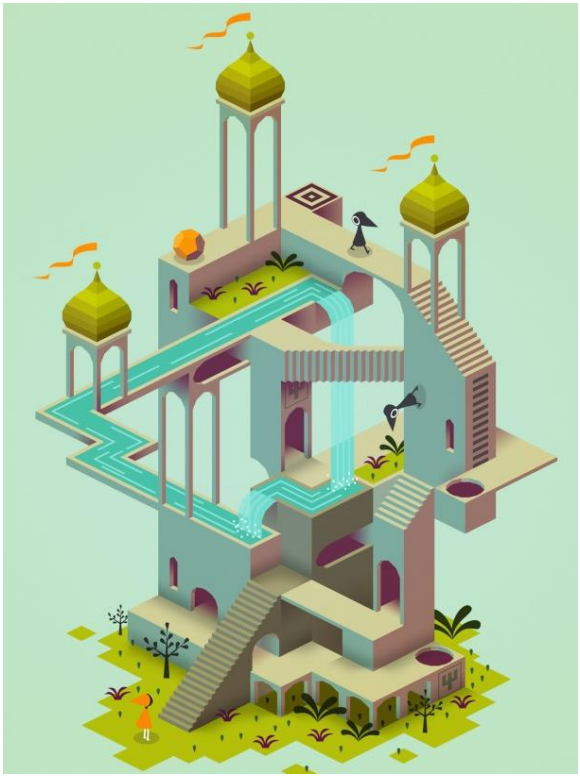


Figure 3.9: Monument valley game's screen-shot **(Url-38)**

3.3 Illusion and Product Design

In this section, the relationship between illusion and the product design will be discussed. Although product design in the field of illusion is not generally developed yet, there are some designers using illusion as a design concept or part of the visual identity of products in their designs. From long time ago, that the field of illusion was discussed by the philosopher, people always interested in the mislead perception. Now some designers come to the idea of using this interest as an additional value to the product. Thus, it is important to analyze the products that have an illusional aspect in addition. Therefore, a set of sample products had been selected to analyze their features and effects on the users. It seems that designers' illusional products, can be divided into three main categories, that first group is called 'Appropriation of illusion in design', in which, designers directly use a traditional optical illusion (discussed in the chapter 2.5) in their products. Second group is called 'Design inspired by illusion' which designer inspired from a well-known optical illusion and create a product. The third group is called 'Design creating an illusion' where the illusion clues cannot be found directly as in the traditional optical illusion and the

designed product creates a new illusion itself. In the following sections, these categories are expanded and analyzed by various samples in order to have a better outlook.

3.3.1 Appropriation of illusion in design

'Appropriation of illusion in design' can be define as a product which designer directly use a well-known traditional illusion (which mentioned in Chapter 2.5) in a product.

It is a psychological topic that people always like to buy and share interesting objects, and illusion maybe is one of the most interesting phenomenon which human beings know. Many designers who find out the interest in illusion try to combine product and illusion to attract the user. In this section, some products will be shown by which an illusion is transformed directly into a product.

The first example in this section can be a bookshelf called '180º' by Spain-based studio 'Cuatro Cuatros' (Figure 3.10) which is same as café wall optical illusion (described at chapter 2.5.2.2). Usually observer expects the shelf's floor stay horizontal and parallel; but in this product, designer fooled the viewer mind by using the café wall illusion.

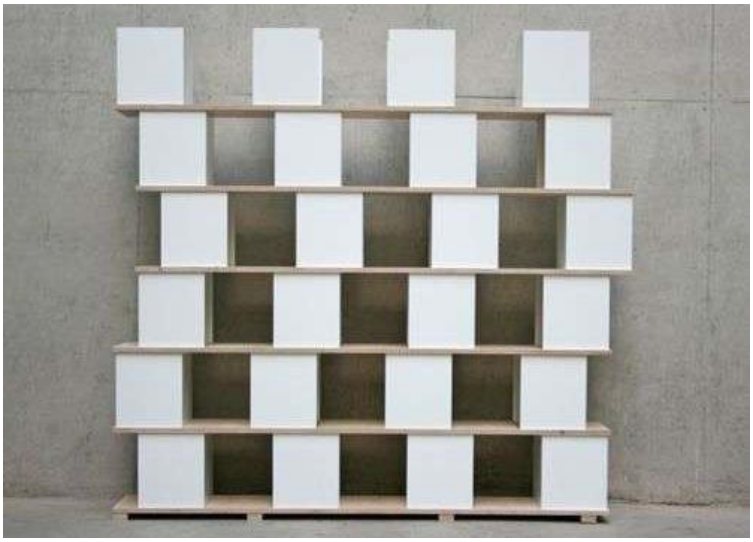


Figure 3.10: Café wall illusion bookshelf **(Url-39)**

Although, designer does not use the actual café wall colors in the shelf the contrast of light and shadow perceive the unparalleled illusion. Maybe illusion could get stronger if the designer closed the back of the shelf with a black sheet.

Another famous illusion, which is used in several products is Necker illusion that was discussed in the chapter 2.5.2.1. One of these products is a decorative candlestick, which is presented in the Figure 3.11a. It is just a line drawing Necker cube itself plus, three candle. Similarly, a necklace is designed too, by using the same illusion ,which is illustrated in the Figure 3.11b. For both of them, the designer directly adds an illusion into the product to perceive the perspective illusion effect.

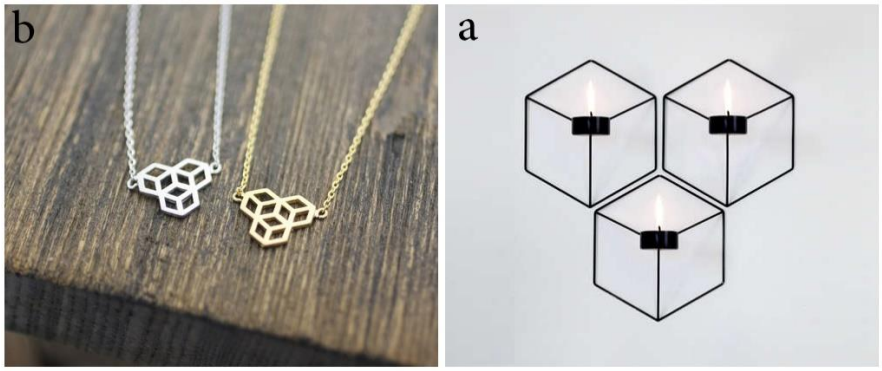


Figure 3.11: Necker illusion as product **(Url-40) (Url-41)**

It seems that Necker illusion is popular among designers, there is another product called 'The Illusion bench and table' designed by Jean Claude Cardiet that mentioned in the Figure 3.12. The bench illustrates the Necker illusion in 3D while it is 2D on the table. The designer might have tried to show the relation between 3D and 2D of an illusion or, maybe he wanted to demonstrate the role of designer to creating real objects from sketches.

In addition, this product can be compatible with the other category of design inspired by illusion, but it is more like to fit in this group because, since the designer directly uses the pattern on the table surface and turns the two-dimensional shape into a three-dimensional object as the chair.

Figure 3.12: The Illusion bench and table by Jean Claude Cardiet **(Url-42)**

Another example of using Necker's illusion in design can be name as 'Cubious' which is a shelf designed by Kristina Lindqvist. As it demonstrated in the Figure 3.13, this shelf misleads observer's perspective perception due to Necker illusion. Same as the previous product, it can fit in the category of 'design inspired by illusion' too, but here the designer directly uses the Necker Cube, extrude it and create a bookshelf; so, it appears more harmonious with the category of Appropriation of illusion in design.

Figure 3.13: Cubious shelf by Kristina Lindqvist **(Url-43)**

The Hermann grid illusion, which has been described in the chapter 2.5.1.1, is another illusion that some designers use as a pattern source in their products. Figure 3.14 shows one necklace and a laptop bag which are patterned with this illusion. As it noted before, in this illusion, the gray dots in the intersection of white lines appears and blinks because of eye error. It may attract other people to look at these products.

Figure 3.14: The Hermann grid illusion on a bag and a necklace **(Url-44)**

‘Hypnosis sofa’ is the name of a couch that is designed by Rafael Simones Miranda. As it shown in the Figure 3.15, he is using the Kitaoka’s Rotating Snakes illusion (mentioned in the chapter 3.2.2) to coating his sofa. Anyhow, this sofa can be suitable to the current category because, the designer directly use a well-known illusion as the pattern of the sofa.

As it is mentioned before while the observers are looking at the rotating snakes illusion, they begin to move while it is a still image. Therefore, the same thing has happened to the sofa; it feels like the sofa is moving when someone gets closer or sitting on it.

Figure 3.15: Hypnosis sofa by Simones Miranda **(Url-45)**

The impossible objects are another illusion, which contains some kind of mystery in it. People always mistakenly believe that impossible illusion can be existed just on the paper. It is always marvelous for people to see an impossible drawing in reality as an object and this is designer’s job to make the dreams come true.

A good example of using an impossible illusion as a product can be the ‘Impossible Triangle Vase’ designed by Cuatro Cuatros. As it shown in the Figure 3.16, the illusion can be seen just from the specific angle, which is demonstrated in the left vase. However, the question is, how could people realize this illusion? It is a beautiful vase but it is hard to accept it as a decorative illusion, which everybody recognizes, because people should seek around the object to find the exact viewpoint to see the illusion; although, there is no doubt that from the aspect of realization an idea this vase could be a masterpiece.

This product can be included in two categories such as ‘Appropriation of illusion in design’ and ‘Design inspired by illusion’; but it appears to be more suitable for the first category because, the designer picks a recognizable well-known illusion and transforms it in to a three-dimensional real life object. In other words, direct usage an illusion in this product is more significant than the inspiration aspect.

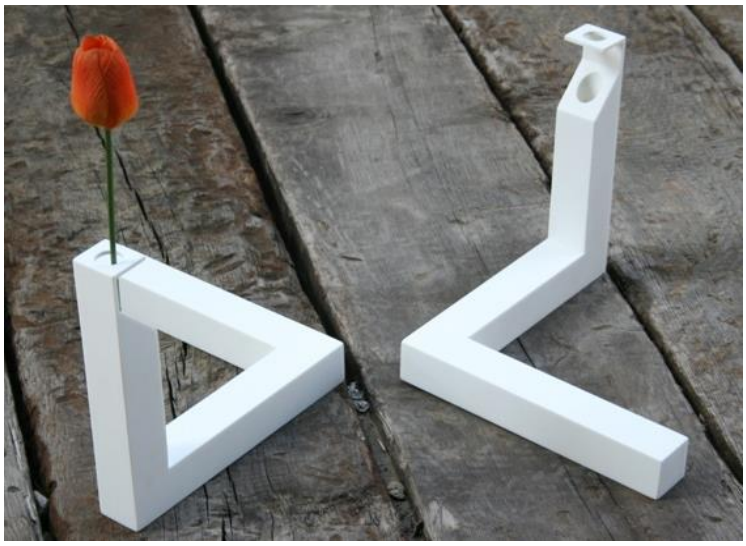


Figure 3.16: Impossible Triangle Vase by Cuatro Cuatros **(Url-46)**

As another impossible product example, a bookshelf designed by John Leung can be noted. As it is illustrated in the Figure 3.17, the enigma of the bookshelf refers to the number of its steps; the right side of a shelf has three steps while the left side has four steps. The brilliant structure of the steps and connection of them easily mislead the mind to the illusion of three or four steps. Just like the previous example, this bookshelf can be classified into two categories such as ‘Appropriation of illusion in design’ and ‘Design inspired by illusion’; but the direct usage of an old illusion in this product is more emphasized when considering the inspiration aspect of it. Thus, it has been decided to be placed it in this category.

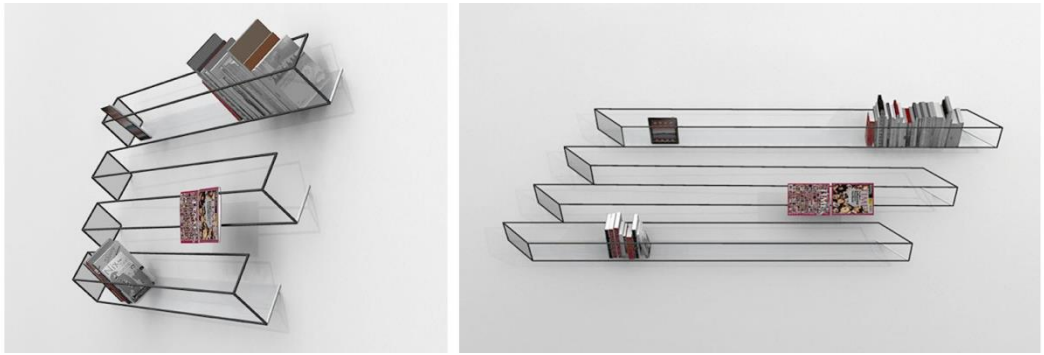


Figure 3.17: An optical illusion bookshelf by John Leung **(Url-47)**

Tania Hennessy is a Canadian jewelry designer and the owner of AROHA SILHOUETTES Company that uses impossible objects to design jewelries. Most of her works are two dimensional, like the rectangle illusion necklace which shown in the Figure 3.18. This is an impossible object illusion directly used as a necklace while it is perceive like a three dimensional shape. As it is clearly seen from the Figure 3.18, the designer directly cuts one of the Escher's sketches as sketching lines and makes a 2D necklace; therefore, this object can be counted as a 'Appropriation of illusion in design' product.

Figure 3.18: Rectangle illusion necklace by Tania Hennessy **(Url-48)**

3.3.2 Design inspired by illusion

'Design inspired by illusion' is one of the defined categories to classify the field of optical illusion and product design. As it is obvious from the topic's name, products in this category get inspired from the well-known traditional optical illusions. In general, the key element of this category is the inspiration.

One of the most important inspiration from illusion in design can be seen in army in the field of camouflage. The appearance of uniforms or painting the military equipment in a single color, return to much older times about 4th century, but the camouflage as an illusion for the first time can be referred as the Dazzle Camouflage for battleships during the World War I, which is demonstrated in the Figure 3.19. An English artist called Norman Wilkinson (1878–1971) covered battleships with a complex pattern of geometric high contrast shapes. At the first sight, it seems that unlike other kind of camouflage, the dazzle attracts attention instead of hiding the ship, but actually, this camouflage misleads the enemy to estimate the distance, speed and the heading of the ship. The same strategy can be found in nature as the skin

pattern of giraffe, zebra and tiger specially when they are running (Murphy & Bellamy, 2009).

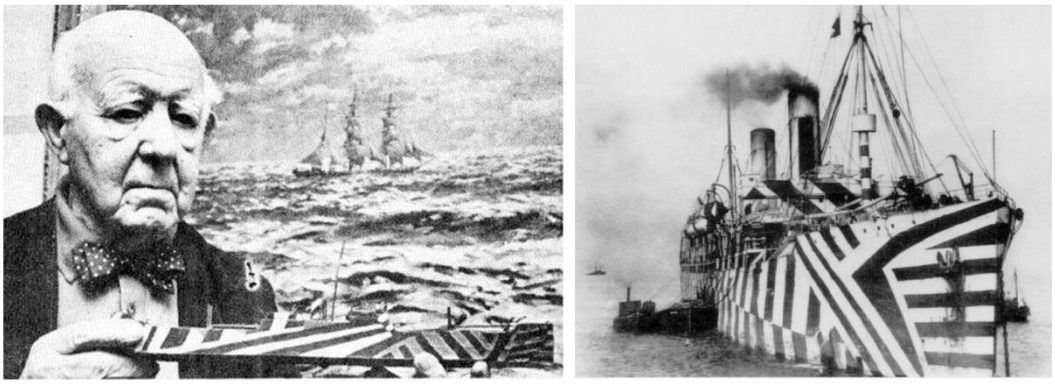


Figure 3.19: Norman Wilkinson, with a dazzle camouflage model in his hand and at the right an England battleship with dazzle camouflage **(Url-49)**

The dazzle camouflage led to more studies about the colors, hues and illusions which enhanced the camouflage efficiency. Today, camouflage design has become one of the important parts of military researches and as it is illustrated in the Figure 3.20 the result is hundreds of camouflage patterns to cover soldiers and equipment in different environmental conditions.

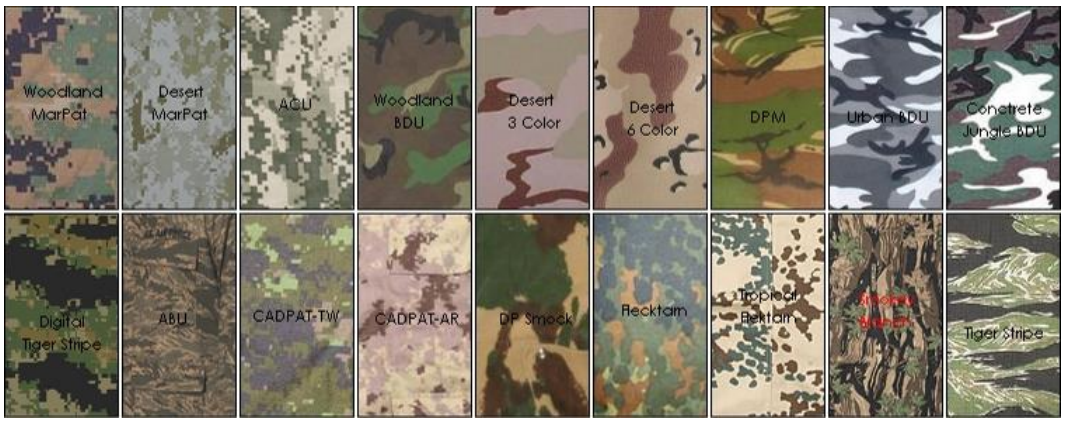


Figure 3.20: samples of camouflage patterns **(Url-50)**

Separated from the military, inspirations of illusion can be seen in every-day life products too, such as a decorative candle holder called ‘Flat light’ designed by Nir Chehanowski which shown in the Figure 3.21. This candlestick looks like a real 3D object, but it is a 2D object, which seems like a real 3D one. Actually designer is inspired from Anamorphosis technique (discussed in the chapter 3.2.2) to make this 3D perception.

The only negative point that might be seen in this candlestick, just like ‘Impossible Triangle Vase’, which noted in the previous section, that the illusion can only be perceived from a specific viewpoint.

Figure 3.21: Flat-light candlestick by Nir Chehanowski **(Url-51)**

Another illusion that many designers are inspired from is the fiction illusion. As it is noted before in the chapter 2.5.2.4, human brain is used to recognize familiar shapes and has a tendency to make an assembled image from diffuse elements. There are a few examples proving the fact that designers can use this brain capacity to create products. For example, a bathroom sink called ‘Waterfall’ designed by a Canadian company CBD Glass (Contemporary Bath Design) which is shown in the Figure 3.22. This sink is made from opaque glass that is perceived as the water falling from an invisible sink because our mind tries to complete the nonexistent object from the observable elements.

Figure 3.22: Waterfall sink from CBD Glass Company **(Url-52)**

Another example for the same illusion (fiction illusion) can named as ‘Phantom Table’ designed by John Brauer. As it demonstrated in Figure 3.23, this is a dining table made out of carbon fiber plastic and it seems like a tablecloth with no table

floating in the wind. Actually this perception comes from our past experience about the table and tablecloth; the effect of sharp edges of the table on the tablecloth and soften waves of a fabric in the air in this product easily deceive human mind.

In fact, this table can fit to the third group of 'Design creating an illusion' too, because, it can be counted as an illusion itself; but, it seems more suitable for the current group since the designer is inspired from fiction illusion to create this product.

Figure 3.23: Phantom Table designed by John Brauer **(Url-53)**

Being inspired by the fiction illusion can also be chased in the works of 'Oki Sato' a Japanize artist and the owner of 'Nendo' company. For instance, his 'Fadeout-chair', its back and seat are made of wood and the legs are clear acrylic, painted like the wood pattern (Figure 3.24). Slightly fading color of the legs gives the feeling that the chair is placed in the shallow water of fog. It can be perceived that this chair can create a virtual sense of environment itself.

Figure 3.24: Fadeout-chair by Oki Sato **(Url-54)**

Another artwork of the same artist called ‘Outline table’ that can be seen in the Figure 3.25. This table is inspired by the combination of fiction and Necker cube illusions. As it is obvious, although the outlines are not complete, our mind can recognize the total shape of the table containing three cube stands side by side, but the uncompleted and thin outline is perceive as the instability for the table. It seems that designer tries to induct the shape of three cubes in this product simply by using minimum elements of lines.

Figure 3.25: Outline table by Oki Sato **(Url-55)**

‘Tokyoflash’ is the name of a watch company in Japan, which produces interesting watches. One of the most interesting products of this company is ‘KISAI Optical Illusion Watch’, which is illustrated in the Figure 3.26a. Actually, the manner of showing the time is inspired by Op-art calligraphies like the sample demonstrated in the Figure 3.26b. The image contains crossed lines, the difference between the zigzags lines demonstrates the time; the right lines lent to the right show the numbers and the lines lent to the left illustrate the background while the combination of them creates the illusion of this watch. Indeed, reading the time is hard in this product, but it seems that this is the point of designing such a watch since someone who will be buying this watch is able to read it easily; psychologically the this watch might make the owner proud of him/herself for achieving something that is hard to do in the first glance.

This watch can be located in the third subset (‘Design creating an illusion’) as well, because it seems that this product creates a new optical illusion itself; but actually, the designer is inspired from the op-art graphical illusions and digitalized it as a watch.

Figure 3.26a: An op-art calligraphy sample **(Url-56)**

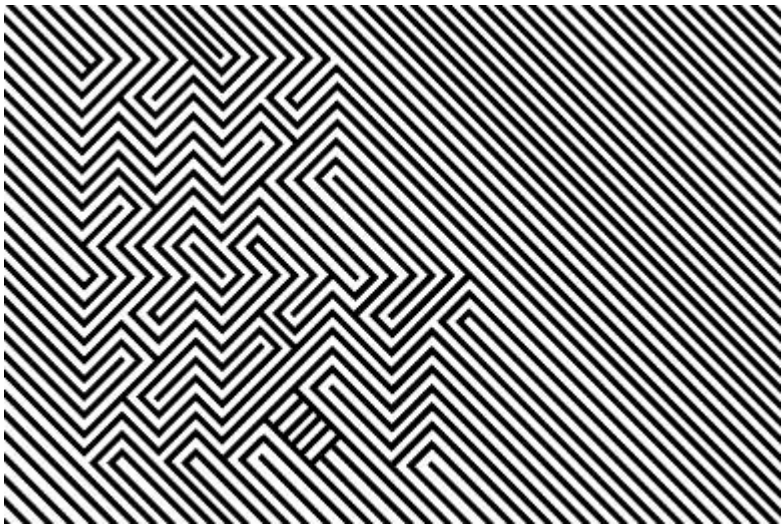


Figure 3.26b: An Op-art calligraphy sample **(Url-65)**

3.3.3 Design creating an illusion

The third group on the product design in optical illusion field classification is "Design creating an illusion". The key element of this group is the unique illusion, which a product causes. As Phillips (2015) describes, designers are known as innovative persons, because their job is to create new phenomenon. In the field of illusion and design, although many products use an illusion directly in design or inspired from an illusion, sometimes designers' innovation abandon to utilize the traditional illusions (which mentioned in the chapter 2.5) and they attempt to create a product, which is present as a new illusion itself.

‘Shady Illusion Lamp’ can be an example of a product, which is an illusion itself (Figure 3.27). This lamp was designed by ‘Yuki Yamamoto’, which used aluminum and plastic as the body and the LED (light emitting diode) lamp to illustration. The LED lamp was placed in the little trapezoid-shape hole in the top of the bar that caused the shade on the wall. This shade reminded an invisible the table lamp cap to the observer.

Figure 3.27: Shady Illusion Lamp design by Yuki Yamamoto **(Url-57)**

For another instance, it is good to name an object collection called ‘Kishu’ designed by British artist ‘Maya Selway’. The collection contains objects that seem like unfinished sketches of vases, candlesticks, bowls and bottles that the two examples of them, are shown in the Figure 3.28. Designer tries to demonstrate the beauty of sketches in the real object by using thin rod as the line to show the gestalt of objects. Although the objects are not solid, they are perceived as the real objects within the sense to the viewer.

In fact, these products could be counted as the second group (‘Design inspired by illusion’) too because, it seems like a kind of fiction illusion, (discussed in the chapter 2.5.2.4) which the human eyes complete the nonexistent parts. Nevertheless, the fiction illusion is not the only illusion of this product; also, the new illusion it makes by transforming the 2D hand-sketches to a 3D objects is more highlighter that fiction aspect.

Figure 3.28: Two sample of Kishu collection by Maya Selway **(Url-58)**

Another good example that shows the designer innovation to create a new illusion is called ‘Good Vibration’ storage unit designed by Italian designer ‘Ferruccio Laviani’ that is demonstrated in the Figure 3.29. His masterpiece wooden artwork creates the visual noisy illusion, which reminds the old television noise or computer effect on the picture.

Figure 3.29: Good Vibration by Ferruccio Laviani **(Url-59)**

The next designer is ‘Angela Jansen’ who is a Dutch designer that combines the design and technology to create the ‘Floating Lamps’ shown in the Figure 3.30. The

illusion in this lamp is the floating piece of its cap. The electromagnetic system (which is invented by her father ‘Ger Jansen’) on the cap makes it really hanging in the air while the LED lamps illustrate the empty space between two parts of the caps. It seems that designer tries to keep the classic form of the table lamp to emphasize on the floating illusion part of her design.

Same as the Kishu collection (Figure 3.28), because of this lamp’s ‘fiction illusion’ aspect, it could be arranged in the second group (‘Design inspired by illusion’) too; but, the bolder ‘floating illusion’ situation , led to prefer it as an example of the third group (‘Design creating an illusion’).

Figure 3.30: Floating Lamps by Angela Jansen **(Url-60)**

‘Inception chair’ can be named as another example of product as an illusion which is shown in the Figure 3.31. This chair designed by an American artist ‘Vivian Chiu’ that includes ten parts assembled together while each part is look like the structure of a simple chair. This chair named after the inception movie and she described “*because no one really knows what is happening at first look*” (Kapila, 2011). As it is obvious in the Figure, the illusion this chair makes is the infinite visual perception from different angle. This effect reminds the infinite repeating of an object’s image between two parallel mirrors.

Figure 3.31: Inception chair by Vivian Chiu **(Url-61)**

Another product that performs an illusion itself called ‘Wine Bottle Holder’ design by ‘Shahar Peleg’. As it is presented in the Figure 3.32, this product is a chain, which rings are delicately welded together in a specific path and totally became a unified solid object. Actually, it can be described as the intersection point between design and physic; when a bottle placed in the holder, the bottle weight and center of its mass have been neutralize by the holder while creating the illusion of instability. Indeed, the strong feel of illusion in this product, occurs because instead of the bottle, it seems that chain is hanging from it. Sometimes the interaction of two objects on each other may lead to an illusion effect.

Figure 3.32: Wine Bottle Holder by Shahar Peleg **(Url-62)**

To have better view about the interaction of two objects to make illusion, it is good to name the ‘Treasure Mug’. This mug which shown in the Figure 3.33, seems like an ordinary mug which is non-horizontally cropped. Therefore, it stands with a little slope when it is placed on the table and feels like the mug is sinking in the table. It could be said that the mug changes the table`s material perception.

Figure 3.33: Treasure Mug looks like sinking in the table **(Url-63)**

As another product demonstrating an illusion is named ‘Shadow Chair’ by British designer ‘Chris Duffy’, which is shown in the Figure 3.34. At first glance, it looks like his chair disobeying the gravity and standing on just two legs. The illusion occurs by the shadow-shape metal base under the chair, which supports the balance of the chair. At the first glance, human mind ignores the shadow as part of the chair structure but then after a while, the brain solves it logically.

Figure 3.34: Chris Duffy and his shadow chair **(Url-64)**

3.4 Chapter Summary

The first section of this chapter discusses the applications of illusion which is divided into three subsets that are ‘illusion in nature’, ‘art and illusion’, and ‘architecture and illusion’. In the first subset, the different types of illusion in nature are explained. The camouflage can be named as the most important of them exemplified by the chameleons and praying mantises. Next category describes the relation between art and illusion and named as Trompe-l'œil technique as a way of creating illusion in paintings. Then the optical illusion art referring to op-art is explained and demonstrated by the examples of this field. For the other subset, the field of illusion and architecture is explained going back to the ancient world and is exemplified by the Parthenon temple. Then, it is demonstrated by a contemporary building, which used café-wall illusion as the exterior decoration. Afterwards, a game named as Monument Valley, which uses illusion as a building to create a puzzle, is given as an example.

For the next section, the relation between illusion and product design is discussed and it is mentioned that -although the usage of illusion in product design is still very limited- there are some designers using illusion as a design concept or part of the visual identity of products in their designs. To analyze the products in the field of

illusion, examples are distributed into three categories such as ‘Appropriation of illusion in design’, ‘Design inspired by illusion’ and ‘Design creating an illusion’. The first category includes the product examples, which the optical illusion is used directly in them. The illusions that mostly used in this category are café-wall illusion, Necker cube illusion, Hermann grid illusion and impossible objects illusion. The next category is design inspired by illusion, which illustrates the examples of products which designers have used one or more features of an illusion, such as gestalt psychology or the after effect of a given perception, to design a product. For this category, firstly the topic of camouflage is discussed Then Norman Wilkinson has been referred to , since he designed a dazzle camouflage for battle ships during the World War I. Afterwards, a few other everyday life products are analyzed which have been inspired by illusion. The last section is called Design creating an illusion; as it has been noted, designing in this category absolutely depends on the designer`s creativity because the product becomes an illusion itself and a phenomenon which does not exist physically is perceived. Then, some products are exemplified in order to see how a product can be an illusion itself and their effects on perceptions of the user.

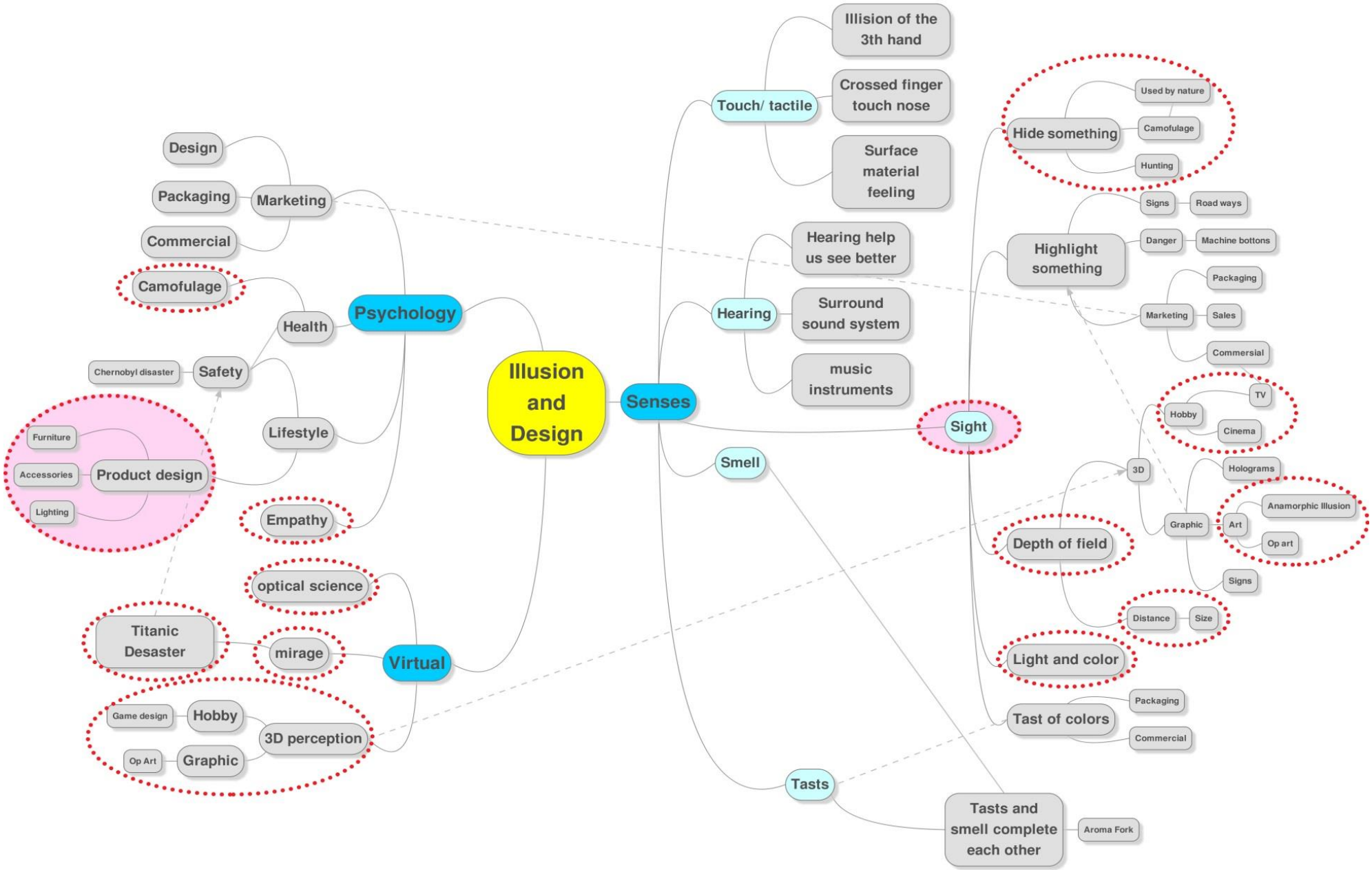
4. METHOD

When an illusion is experienced, there is always an attention-driving feature in an illusion. What if the same attention-driving feature is used as a pro for design? First, the reason of selecting illusion and design as a research topic depends on this question. The other questions forming this study can be summarized as; "What is the relation between illusion and design?", "How can an illusion affect design?" and "Why do some designers use illusion in their designs?" Bearing these questions in mind, the methodological approach for the study is constructed around the following subtitles below.

4.1 Mind Mapping

First, a mind map (which can be seen in the Figure 4.1) is done to have a general overview about the subject of illusion and design, and it has helped to organize information visually. Generally, it can be said that mind maps can be used to identify the relations, visualize the structure, and classify ideas, as an aid to studying and organizing information, solving problems, making decisions, and writing (Willis, 2006). However, after all the concepts that the researcher thought are put out as a mind map, it is accepted that the illusion and design is a vast field of study to be fit just in a single thesis. In addition to this, although we have five major senses, the most of the information from our surroundings are received by the eyes, which make sight a very important part of our lives. Thus, it is purposed to limit the subject of the study to the theme of 'optical illusion' and 'product design' as it is obvious in the mind map where they are marked in pink highlights. According to this, two main chapters had been selected which are 'optical illusion' as literature review chapter and 'illusion and design' as illusion and design chapter. After depicting certain headlines, a literature review is prepared, focusing on optical illusion, eye anatomy, vision and different types of optical illusion.

Figure 4.1: Illusion and design Mind map



4.2 Literature Review

The first part of literature review is a brief history about illusion in order to have a background about this phenomenon. Since this research is based on optical illusions, the next section shortly describes the structure of human eye for to figure out the reason of optical illusion occurrence. Then the concept of vision is explained as an essential element in order to see objects to different types of vision and the illusion they may cause. Following part demonstrates the different types of illusion beside a few examples to became familiar with the perception and formation of each one. Actually, in this part, a model suggestion has been presented to classify the different types of optical illusion; since, there is no certain arrangement found in the field of optical illusion during the research; the given classification is organized via the common points of the resources that have been discussed in this field.

The data and information for the literature review chapter are mostly collected from reference books based on physic, optic, psychology and design philosophy, which can be regarded as one of the most traditional ways of research. In addition, most of the recently published research papers, literatures and newspaper articles used in this research are found via Internet search in order to receive the up-to-date knowledge.

4.3 Sampling

The first section of the chapter 3 (‘illusion and design’) has discussed the application of illusion for to have a general outlook of how an illusion might be used by nature, artists and architects. Then in the second part, the field of illusion in the industrial design has been analyzed by focusing on selected examples. In this part, a model suggestion has been provided to classify the field of optical illusion in product design. This arrangement has been prepared to describe the manners, which designers may use, to apply illusions in their products.

To enhance the knowledge of using illusion in design, this section has been divided into three categories which include ‘Appropriation of illusion in design’, ‘Design inspired by illusion’ and ‘Design creating an illusion’ to see why and how designers use illusion to create their designs.

The example collection has been started by searching the Internet. There are mostly two ways for gathering the examples through the Internet. One way is via direct access to the related websites, which have been already reputable for the designer or company. Another way of using Internet as a source has been through the common search engines like 'Google' and 'Bing' to collect examples from non-famous designers and companies by typing the keywords of related subject such as illusion, design, illusion product. The point of sample collection in this manner has been an up-to-date, fast way and the observable variety is impressive.

4.4 Survey

In this thesis, a short exemplar survey has been prepared to clarify the thoughts of the researcher and investigate the presented approach about the model suggestion in the intersecting field of illusion and product design. By this short survey, it is also tried to get the other designers' opinions, answers and approaches about the research questions (Why is it important to study about illusion and design? Why do designers use illusion in their products? How do designers use illusion in their design?) , an exemplar survey is conducted in two phases such as a short questionnaire and a photo assemblage as seen in Appendix 1.

The participant group is in the range of 23 to 33 years old age and they are master and doctorate students of industrial design and architecture, who are educated in the field of design. Ten participants have taken part in the survey. The questions are answered in an one-on-one dialogue environment and each survey takes about 20 to 40 minutes to answer. The aim is not to get a generalized outlook but to get the hints about personal approaches so working with a limited number of participants is not regarded as a problem.

The survey consisted of two main parts. In the first part, the photos of 12 sample products were printed on separate cards which have been selected randomly from the discussed products of chapter 3.3 and each participant was asked to arrange them under three categories such as; 'Appropriation of illusion in design', 'Design inspired by illusion' and 'Design creating an illusion'. Here, the participants were asked to classify and make the arrangements under the topics depicted by the researcher. Afterwards a photo was taken from each of the arrangement set as it is seen in Figure

4.2.A, and expected arrangement's photo is also demonstrated in the Figure 4.2.B. In the second part four questions about each product were asked (as it seen in Appendix 1) to understand the other designers viewpoints about the specific illusion used for each product. The multiple-choice questions were limited the participants mind to the given answers, so in order to get a wider answers, questions types are selected as open-ended questions.

Figure 4.2.A: Arrangement examples set by participants

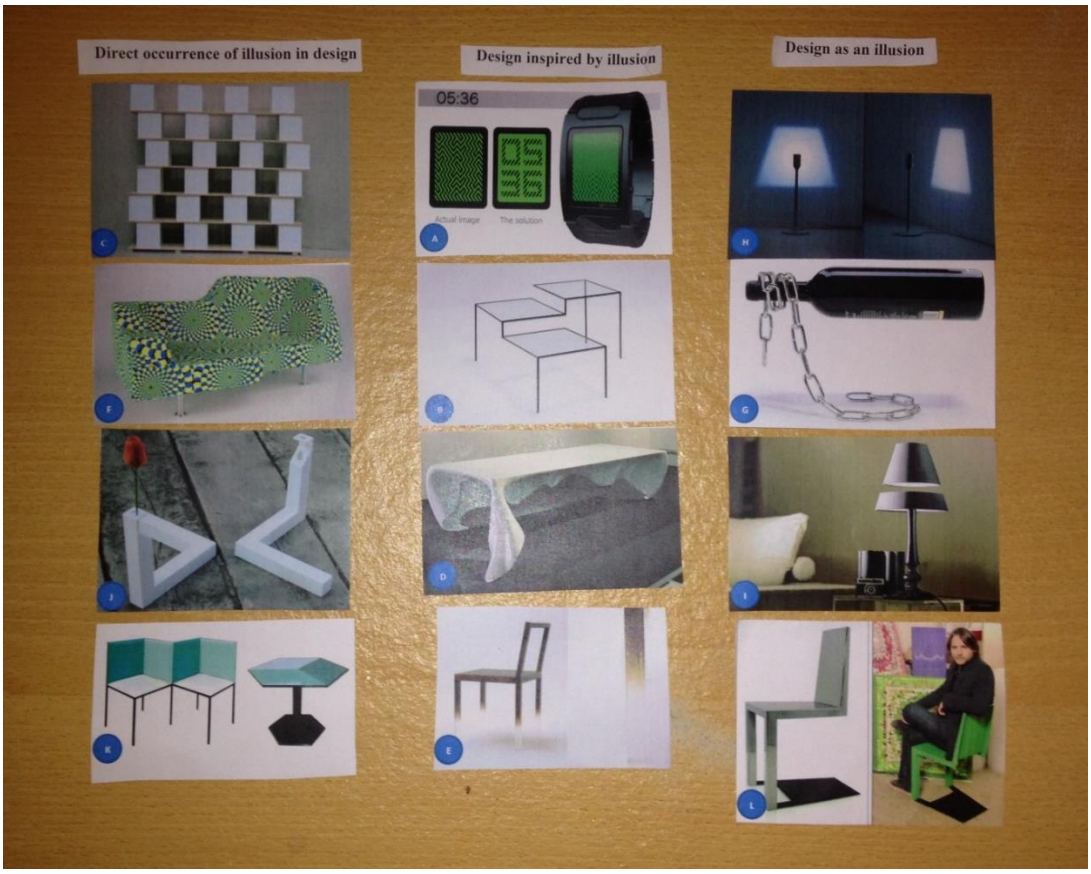


Figure 4.2.B: Expected arrangement

4.4.1 Findings

The chart below shows the dispersion of 12 products in three groups of 'Appropriation of illusion in design', 'Design inspired by illusion' and 'Design creating an illusion' which have been chosen by the participants. The highlighted areas are the expected answers that previously have been classified in the chapter 3.3.

Samples No.	1) Appropriation of illusion in design	2) Design Inspired by Illusion	3) Design creating an illusion	Not Fit in Any Group
A	5/10	2/10	2/10	1/10
B	-	9/10	1/10	-
C	8/10	2/10	-	-
D	1/10	4/10	5/10	-
E	1/10	5/10	4/10	-
F	10/10	-	-	-
G	2/10	1/10	7/10	-
H	-	1/10	9/10	-
I	2/10	1/10	7/10	-
J	5/10	5/10	-	-
K	6/10	4/10	-	-
L	1/10	4/10	4/10	-

* The expected answer

* The product received different answer than expected

Chart 4.1: The dispersion of 12 products in three groups

Product 'A' illustrated the KISAI Optical Illusion Watch from Tokyoflash Company which is shown in the Figure 4.3. According to the Chart 4.1, this product was classified in the second group of 'Design Inspired by Illusion'; however, half of the participants (5/10) put it under the group of 'Appropriation of illusion in design'. Participants are mostly demonstrated that they put it in this category, because of designer directly used an op-art as a pattern to illustrate the time. In addition, one of

the participants expressed that *"he cannot locate this product in any of those three categories because; it could be counts as an electronic interface design*."

Participants told that illusion in this product showed the designer innovation and aimed to challenge the user while describe these with keywords like '*unique, attractive, fun, enigma and coding'*. Also one of the most the negative aspect of this product which mentioned by the participants is the '*difficulty in reading the time'*.

Figure 4.3: KISAI Optical Illusion Watch from Tokyoflash Company **(Url-56)**

Card 'B' is Outline table by Oki Sato (Figure 4.4). Considering to the Chart 4.1, the expected answer was the second category of 'Design Inspired by Illusion', and also most of the participants (9/10) rated this subset as the most qualified category for this product. They resemble this product with the line sketching perspectives and Necker cube illusion.

The participants described that the illusion in this product showed the stability in instability and also made the eyes to follow the lines and also it showed the combination of 2D and 3D design. Unique and creative design could be named as the common answered positive aspects which mentioned by the participants; while, *unstable* and *unsafe perception* were noted as the negative points of this product.

Figure 4.4: Outline table by Oki Sato **(Url-55)**

Product ‘C’ is known as cafe wall illusion bookshelf which is demonstrated in the Figure 4.5. By referring to the Chart 4.1, it is obvious that same as most of the participants’ choice (8/10), the expected answer is the ‘Appropriation of illusion in design’ too.

As the participants expressed it, this product is a 3D version of an old illusion which they knew, and this illusion made the bookshelf’s floors seem *un-parallel*. They mentioned the positive aspects of this product with the keywords like *interesting, harmony and symbol*; but also on the contrary some mentioned that the perceived *illusion is not as strong* as the original wall and *low space capacity* of bookshelf as the negative aspects of this product.

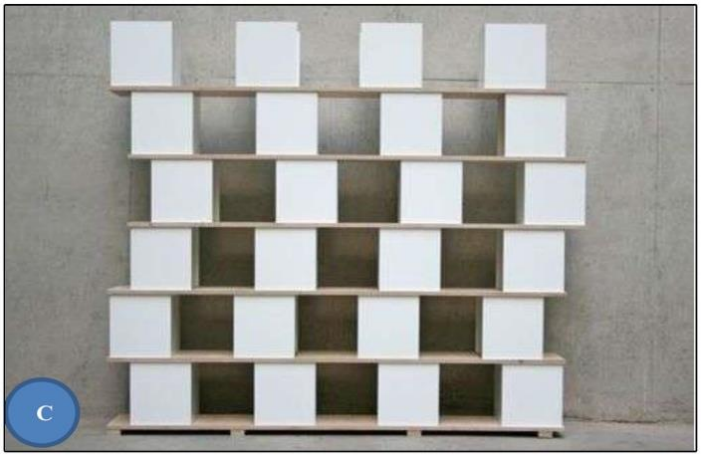


Figure 4.5: Café wall illusion bookshelf **(Url-39)**

Product ‘D’ is ‘Phantom Table’ designed by John Brauer that can be seen in the Figure 4.6. According to the Chart 4.1, this product was put in the second group of ‘Design Inspired by Illusion’ but most of the participants 5 of 10 people put it under

the group of ‘Design creating an illusion’. Participants demonstrated that they put it in this category, because the designer created a new illusion in this product, while only 4 of 10 people put it in the expected answer category.

In total, participants expressed that illusion in this product made *a complex new table* and *added an environment* to the room by giving the wind perception; and also gave it a *ghost or flying board* shape.

The negative aspects explained by the participants could be said as, ‘*seems not strong enough*’, ‘*not useful*’, ‘*more like sculpture than table and scary*’; while the positive aspects described by the words like, ‘*pleasant, attractive, environmental and movement in solid object*’. In addition, one person described that ‘*this product is more suitable as a decorative object for an office than a house*’.

Figure 4.6: Phantom Table designed by John Brauer **(Url-53)**

Product ‘E’ is illustrated in the Figure 4.7 which is Fadeout-chair designed by Oki Sato. By referring to the Chart 4.1 it could be obtained that this product was classified under the second category which was ‘Design Inspired by Illusion’ and also 5 of 10 participants voted this chair to the same subset. Besides, four people believed that designer created a new illusion by this product.

As the participants mentioned it, designer made this chair perceived like floating or flying in the air and also fading color on the legs made it feel like a heavy fog lying on the floor. The positive aspects of this product, according to the participants, could be named as; *cool, simple and magical*; and negative aspects, which they mentioned, are ‘*seems not much comfortable*’ and ‘*not so amazing design*’.

Figure 4.7: Fadeout-chair by Oki Sato **(Url-54)**

Product ‘F’ is ‘Hypnosis sofa’, which was designed by Rafael Simones Miranda shown in the Figure 4.8. As it is illustrated in Chart 4.1, this product classified in the category of ‘Appropriation of illusion in design’ and all of the participants (10/10 people) recognize this illusion and decided to put this product in the same category.

In general, most of the participants believed that using this illusion makes the sofa’s surface feels like moving and actually attracting people at the first sight. They demonstrated the positive aspects with the keywords like ‘*attractive and dynamic’*; while describe negative aspects with sentence like ‘*feel of dizziness after a while, hypnosis effect while resting, not a unique design and ugly’.*

Figure 4.8: Hypnosis sofa by Simones Miranda **(Url-45)**

Product ‘G’ is ‘Wine Bottle Holder’ design by ‘Shahar Peleg’ that shown in the Figure 4.9. According to the Chart 4.1, most of the participants (7/10 people) decided to put this product in the category of ‘Design creating an illusion’; and furthermore, the expected answer is the same category.

Participants expressed that illusion in this product create a *stability in instability* and shows the static rules in design and made the perception of chain hanging from the bottle. The positive aspects of this product according to the participants are, interesting, attractive and nice decoration element. In addition, they named *'not a luxury design', 'not enough stability'*, and *'holding only one bottle'* as the negative aspects of this product.

Figure 4.9: Wine Bottle Holder by Shahar Peleg **(Url-62)**

Product 'H' is 'Shady Illusion Lamp' designed by 'Yuki Yamamoto' (Figure 4.10). By refer to the Chart 4.1, it could be seen that the expected answer was the category of 'Design creating an illusion' and almost all of the participants (9 of 10 people) prefer to put this product the same category as expected.

In total, participants described that the product itself had no specific identity, but shadows gave the effect of an unreal and untouchable lamp-head. The illusion of this product showed the designer's creativity of using light instead of a real lamp-head. *Unique* and *creative* design could be evaluated as the common answers positive aspects, which mentioned by the participants; while, '*not giving enough light*' and '*one effective point of view*' were noted as the negative aspects of this product.

Figure 4.10: Shady Illusion Lamp design by Yuki Yamamoto **(Url-57)**

Product 'I' is 'Floating Lamps' designed by 'Angela Jansen' which is shown in the Figure 4.11. According to the Chart 4.1, the expected answer was the category of 'Design creating an illusion' and also 7 of 10 participants had chosen this as the most suitable category for the product. They all believed that the designer created a new illusion by this product.

To conclude, most of the participants believed that although the upper part of the lamp was really floating in the air but human mind follow the lines and it appeared as a single object; actually illusion of this product challenging the users mind.

The positive aspects of this product, according to the participants, could be named as; '*interesting, attractive, fun, magic, beautiful and combination of science and design*'; and negative aspects which they mentioned are '*unstable upper part and it may fall when the electrics gone*' and '*lots of energy usage of lamp*'.

Figure 4.11: Floating Lamps by Angela Jansen **(Url-60)**

Product ‘J’ is called ‘Impossible Triangle Vase’ designed by ‘Cuatro Cuatros’ which illustrated in the Figure 4.12. As it is obvious in the Chart 4.1, the expected category for this product is the first category of ‘Appropriation of illusion in design’; but half of participants (5 of 10 people) chose the same category and the other half selected the category of ‘Design Inspired by Illusion’ as the most suitable one. However, most of them recognized the Escher’s impossible objects in this product.

In total, participants expressed that illusion in this product makes ‘*a complex and creative new form*’ and ‘*makes an impossible 2D object possible in real life*’. The negative aspects explained by the participants could be said as, ‘*the illusion of the object could be seen just from a specific viewpoint*’; while the positive aspects described by the words like, ‘*impressive, interesting, unique and innovation*’. Also one of the participants described that ‘*this product was not useful as a decorative vase but it was fantastic as a practical design project*’.

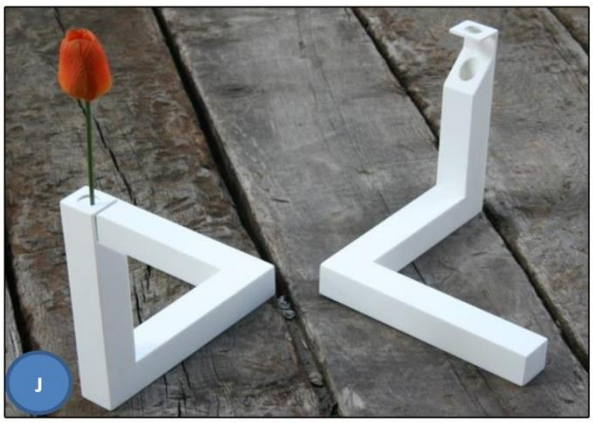


Figure 4.12: Impossible Triangle Vase by Cuatro Cuatros **(Url-46)**

Product ‘H’ is called ‘The Illusion bench and table’ designed by ‘Jean Claude Cardiet’ that is shown in the Figure 4.13. By referring to the Chart 4.1, it could be seen that the expected category for this product is ‘Appropriation of illusion in design’ and also 6 of 10 participants put this product the same category; while other 4 participants chose ‘Design Inspired by Illusion’ as the best group for the product.

As it was expressed by the participants, the illusion of this product demonstrated the ‘*relationship between 2D and 3D objects*’. They mentioned the positive aspects of this product with the keywords like, ‘*harmony and interesting form*’; while mentioned the ‘*useless, ugly and not comfortable*’ as the negative aspect of this product.

Figure 4.13: The Illusion bench and table by Jean Claude Cardiet **(Url-42)**

Product 'L' is named 'Shadow Chair' by British designer 'Chris Duffy' which is shown in the Figure 4.14. According to the Chart 4.1, expected category for this product was 'Design creating an illusion' and 4 participants chose this category. Besides, 4 other participants chose 'Design Inspired by Illusion' as the suitable category for this product.

In general, participants believed that the illusion in this chair made it *seem unbalanced* and *draw attention* of the viewer at first sight. The positive aspects of this product, according to the participants, could be, '*being attractive, fun, feel like magic*' and negative aspects that they mentioned are '*seems not much comfortable*', '*shadow is not look very real*' and '*anxiety about safety*'.

Figure 4.14: Chris Duffy and his shadow chair **(Url-64)**

4.4.2 Survey conclusion:

As the Chart 4.1 illustrated, among 12 samples, only three of them fit in a different category, and also it has been clear from the participants' answers that many of them

did not have much information about the field of illusion. They just recognized some of the famous illusions used in products; for example, all of them recognized the Rotating Snakes on the Hypnosis sofa (Product 'F'). On the other hand, only one of the participants expressed that he could not fit one of the products in any of these categories; all the others agreed with the classification. So, it could be said that the chosen subsets of illusion in product design and the dispersion of the samples could be valid and logical.

Furthermore, according to the comments of the participants about the samples, which are mostly used keywords similar to *'interesting, creative, cool, attractive, unique, innovative and etc.'* these adjectives might demonstrate that the using of illusion to design a product could make it more attractive, interesting and also it could show designer's innovation.

5. CONCLUSION

At the beginning, it has been decided to write this thesis in the field of the illusion and design. However, drawing a mind-map helps to have a wider overview about the topic and it is found out that the illusion and design is a huge field of study to fit in a single thesis. Therefore, the topic is limited to the optical illusion and product design.

The mind-mapping also helps to classify the chapters' title. The literature review chapter generally discusses the concept of optical illusion, its occurrence causes and different types of optical illusions. The next chapter called 'Illusion and Design' which discusses the applications of optical illusion and then analyzes a few samples of optical illusion in product design. Due to the lack of written resources in the field of 'optical illusion and product design', in this chapter an approach has been offered to classify the products, which contains an optical illusion in their design. A short survey has been provided to investigate this suggestion of approach; the participants are selected among the master and doctorate students of the industrial design and architecture program at Istanbul Technical University.

To summarize, this study tries to answer these main questions:

- Why is it important to study about illusion and design?

- Why do designers use illusion in their products?

- How do designers use illusion in their design?

Why is it important to study about illusion and design? The most important application of illusion could be found in nature as camouflage which can also mean the distinction between life and death. As well as nature, designers created camouflage uniforms and patterns for which soldiers wear them in order to deceive and survive from enemies' sight (chapter 3.3.2). In addition, illusion can be used as a safety element like the Anamorphosis child image on the road in Vancouver (chapter 3.2.2) which may psychologically make the driver be cautious as if there was a real child in the middle of the road. Besides the fact that the field of illusion was introduced and known in 450 B.C. the application of illusion has not much developed

since then, especially in the tendency of product design; therefore, because of the reasons mentioned above it is necessary to make a deeper study about the illusion and design.

Why do designers use illusion in their products? Illusions always drive attraction and designer tries to attract people by using illusions in their products. Actually, illusion can give additional value to a product like, creating invisibility, unbalanced feeling, additional environment perception and many other effects. People may point out that an illusional product has fun aspect as a feature, but why does it have fun aspect as a feature? The answer can be found in psychology; this feature is very similar to playing a game. People like to play games because they challenge themselves, and when they defeat a friend or jump into a higher level or solve a puzzle, their body releases Dopamine hormones which make them happy and proud of themselves. Actually, body rewards them and causes some kind of addiction for them in repeating the act of play and moving to the next level or defeating other players. At the same time, it will have no fun and attraction in the end, if someone cannot defeat a friend or solve a puzzle. The same thing might happen for a product which contains an illusion; for example, KISAI Optical Illusion Watch (in chapter 3.3.2). Although it is hard to read the time, many people would like to buy it because the watch itself bears the challenge of reading the time correctly, as the owner succeeds in reading the time correct he/she is satisfied and further more, he/she might want to share that experience and challenge others in doing it. Therefore, designers can create or use illusion in their products to attract consumers and make them satisfied throughout the experience of use.

How do designers use illusion in their design? The approaches which designers apply an optical illusion to a product are the key questions of this research. In fact, applying an illusion to a product as an additional value mostly depends on the designer's creativity and innovative thinking. Application of illusion in product design according to the previous model can be classified into three categories. The first and maybe the easiest way to design a product in the field of illusion is directly transforming an illusion into a product. By this approach, the designer can use a traditional and well-known optical illusion as an outline shape or a pattern or a structure of a product; as well as converting a 2D illusion to a 3D object. The other way, which needs the designer to be more creative, is getting inspired by an illusion

and create new product out of it. In this manner, designer can use one or more features of an illusion, such as Gestalt psychology or the after effect of a given perception, to design a product. The third and maybe the most innovative way to create is designing a product as an illusion. Designing in this category absolutely depends on designer`s creativity because the product became an illusion itself and perceives a feeling which does not exist physically. In general, it can be said that the value of design in the field of optical illusion, relies on the approach of applying the illusion to the product. In other words, trying to find more creative and innovative ways of application may add more value to the product and attract users more.

The limitation of this study is optical illusion and product design; therefore, the illusion of the other senses (including auditory illusion, tactile illusion, tasting and smelling illusion) can be a good topic for further research, not only in product design, but also in the other aspects of design such as safety, packaging, commercial and social design.

In addition, various further applications on the usage of illusion as a design concept might be realized and further theoretical work depending on such applications may deepen the notion of illusion in the field of design where other sensual illusions are also realized. The 3D printers, which are more in use today, will be so helpful to create impossible objects and other illusions. Besides, 3D design programs like 3D Studio Max, Rhino, Maya and other computer programs will be a major aid to create practical designs easier.

REFERENCES

Algom, D. (1992). *Psychophysical Approaches to Cognition*. Netherland: Elsevier.

Ausbourne, R. (2007). *How to Understand, Enjoy, and Draw Optical Illusions: 37 Illustrated Projects*. San Francisco: Pomegranate.

Berns, R. S. (2002). *Billmeyer and Saltzman's principles of color technology*. (F. W. Billmeyer & M. Saltzman, Eds.). New York: Wiley.

Bertalmio, M. (2014). *Image Processing for Cinema* (pp. 227–244). New York: CRC Press.

Broad, W. J. (2012, April 9). A New Look at Nature's Role in the Titanic's Sinking. *The New York Times*. Retrieved from http://www.nytimes.com/2012/04/10/science/a-new-look-at-natures-role-in-the-titanics-sinking.html

Cassin, B. (2006). *Dictionary of Eye Terminology* (Fifth Edit.). Triad Pub.

CNN. (2010, September 9). 3D illusion in street tries to change drivers' attitudes. *CNN's Emanuella Grinberg*. Canada. Retrieved from http://news.blogs.cnn.com/2010/09/09/3d-illusion-in-street-tries-to-change-drivers-attitudes/

Darling, D. (2004). *The Universal Book of Mathematics: From Abracadabra to Zeno's Paradoxes*. New Jersey: John Wiley & Sons.

Delvaux, C. (2013). *The museum of illusions. Optical tricks in art* (p. 192). paris: prestel verlag press.

Eagleman, D. (2011). *Incognito: The Secret Lives of the Brain (Google eBook)*. Knopf Doubleday Publishing Group. Retrieved from http://books.google.com.tr/books?id=nkPj3dNFYwoC&lpg=PP1&vq=Helmholtz&pg=PT52#v=onepage&q&f=false

Eagleman, D. M. (2001). Visual illusions and neurobiology. *Nature Reviews. Neuroscience*, *2*(12), 920–6. doi:10.1038/35104092

Eidenberger, H. (2012). *Handbook of Multimedia Information Retrieval: The Common Methods of Audio Retrieval, Biosignal Processing, Content-Based Image Retrieval, Face Recognition, Music Classification, Speech Recognition,*

Text Retrieval and Video Surveillance (pp. 425–443). Germany: BoD – Books on Demand.

Fernando, A., Worrall, S. T., & Ekmekcioglu, E. (2013). *3DTV: Processing and Transmission of 3D Video Signals*. UK: John Wiley & Sons.

Fiorio, M., Marotta, A., Ottaviani, S., Pozzer, L., & Tinazzi, M. (2014). Aristotle's illusion in Parkinson's disease: evidence for normal interdigit tactile perception. *PloS One*, *9*(2). doi:10.1371/journal.pone.0088686

Gregory, R. L. (2009). *Seeing Through Illusions*. Oxford: Oxford University Press.

Gregory, R. L., & Heard, P. (1979). Border locking and the Café Wall illusion. *Perception*, *8*(4), 365–380. doi:10.1068/p080365

Harris, L. R., & Jenkin, M. R. M. (2011). *Vision in 3D Environments*. Cambridge: Cambridge University Press.

Holman, T. (2008). *Surround sound : up and running*. Amsterdam: Elsevier/Focal Press.

Howard, I. P., & Rogers, B. J. (1995). *Binocular Vision and Stereopsis*. Oxford: Oxford University Press.

Howard, I. P., & Rogers, B. J. (2012). *Perceiving in Depth, Volume 2: Stereoscopic Vision*. Oxford: Oxford University Press.

Illingworth, V., & Cullerne, J. (2009). *The Penguin Dictionary of Physics* (4th Editio.). London: Penguin Book.

Kapila, A. (2011, September 30). Inception Chair by Vivian Chiu. *Icon Eye*. Retrieved from http://www.iconeye.com/design/news/item/9544-inception-chair-by-vivian-chiu

Kuehni, R. G. (2008). *Color Vision & Technology*. North Carolina: AATCC.

Kuriki, I., Ashida, H., Murakami, I., & Kitaoka, A. (2010). Functional brain imaging of the "Rotating Snakes" illusion. *Journal of Vision*, *8*(6), 64–64. doi:10.1167/8.6.64

Levine, G., & Priester, G. W. (2008). *Hidden Treasures: 3-D Stereograms*. New York: Sterling Publishing Company, Inc.

Luckiesh, M. (2013). *Visual Illusions; Their Causes, Characteristics, and Applications*. London: Forgotten Book publication.

McCoun, J., & Reeves, L. (2010). *Binocular Vision: Development, Depth Perception and Disorders* (pp. 1–62). New York: Nova Science Publishers, Inc. ProQuest ebrary. Web. 17 November 2014. Retrieved from http://dl.acm.org/citation.cfm?id=1875108

McDonald, R. (1997). *Colour physics for industry* (2nd ed.). Bradford: Society of Dyers and Colourists. doi:2006494081

Murphy, H., & Bellamy, M. (2009). The Dazzling Zoologist John Graham Kerr and the Early Development of Ship Camouflage. *The Northern Mariner / Le Marin Du Nord*, *XIX*(2), 171–192. Retrieved from http://www.cnrs-scrn.org/northern_mariner/vol19/tnm_19_171-192.pdf

Nicholas, L. (2008). *Introduction to Psychology* (2nd ed., pp. 70–112). Cape Town: UCT Press. doi:213473833

PENROSE, L. S., & PENROSE, R. (1958). IMPOSSIBLE OBJECTS: A SPECIAL TYPE OF VISUAL ILLUSION. *British Journal of Psychology*, *49*(1), 31–33. doi:10.1111/j.2044-8295.1958.tb00634.x

Phillips, P.L. (2015). *Managing Corporate Design: Best Practices for In-House Graphic Design Departments*. Skyhorse Publishing Company. Retrieved from https://books.google.com.tr/books?id=YFJ4BwAAQBAJ

Preston, A. (2010). *Analytic Philosophy: the history of an illusion*. London: Continuum. Retrieved from http://eds.b.ebscohost.com/eds/ebookviewer/ebook/ZTAwMHR3d19fMzc3NDg0X19BTg2?sid=16a78bb9-0767-45e9-95a7-c6540c4fa6fb@sessionmgr115&vid=4&hid=120&format=EB

Prete, F. R. (1999). *The Praying Mantids*. Maryland: JHU Press.

Prinzmetal, W., & Gettleman, L. (1993). Vertical-horizontal illusion: One eye is better than two. *Perception & Psychophysics*, *53*(1), 81–88. doi:10.3758/BF03211717

Saunders, K. (2006). *Turn Eye Appeal Into Buy Appeal: How to Easily Create Powerful Graphic Designs and Persuasive Writing for Marketing Materials, Branding, Advertising and Sales Promotions* (pp. 92–120). Colorado: MacGraphics Services.

Schwab, I. R. (2005). Are you for real? *British Journal of Ophthalmology*, *89*(6), 651. doi:10.1136/bjo.2004.065664

Solso, R. L. (2001). *cognition and the visual arts* (5th editio.). MIT Press.

Solso, R. L. (2008). *cognitive psychology* (8th Editio.). Allyn and Bacon.

Stuartfox, D., Whiting, M. J., & Moussalli, A. (2006). Camouflage and colour change: antipredator responses to bird and snake predators across multiple populations in a dwarf chameleon. *Biological Journal of the Linnean Society*, *88*(3), 437–446. doi:10.1111/j.1095-8312.2006.00631.x

Url-1 < *http://www.sinajdhkajfl.com/asdkjfopoe.html*>, date retrieved 12.07.2014.

Url-2 < *http://en.wikipedia.org/wiki/M%C3%BCller-Lyer_illusion*>, date retrieved 15.07.2014.

Url-3 < *http://www.optometriepraktijk.nl/tag/oct/*>, date retrieved 18.07.2014.

Url-4 < *http://www.ultravision.co.uk/product-range/soft-hydrogel/sam-mf-soft/*>, date retrieved 18.07.2014.

Url-5 < *http://physics.stackexchange.com/questions/65812/why-do-prisms-work-why-is-refraction-frequency-dependent*>, date retrieved 20.07.2014.

Url-6 < *http://en.wikipedia.org/wiki/File:Chromatic_aberration_lens_diagram.svg*>, date retrieved 25.07.2014.

Url-7 < *http://www.ces.fau.edu/nasa/module-2/radiation-sun.php*>, date retrieved 25.07.2014.

Url-8 < *http://www.med.kindai.ac.jp/optho/english/olaboratory.html*>, date retrieved 25.07.2014.

Url-9 < *http://www.vision3d.com/stereo.html*>, date retrieved 25.07.2014.

Url-10 < *http://therealweeklyshow.wordpress.com/2014/01/15/5-more-mind-bending-optical-illusions/*>, date retrieved 27.07.2014.

Url-11 < *http://www.psy.gla.ac.uk/~steve/courses/vision/bex/Bex_Level1.html*>, date retrieved 27.07.2014.

Url-12 < *http://blog.tinywolf.com/119*>, date retrieved 1.08.2014.

Url-13 < *http://digital-photography-school.com/9-crazy-cross-eye-3d-photography-images-and-how-to-make-them/*>, date retrieved 2.08.2014.

Url-14 < *http://www.colorstereo.com/texts_.txt/aboutstr.htm*>, date retrieved 2.08.2014.

Url-15 < *http://www.pinterest.com/pin/497084877593598848/*>, date retrieved 2.08.2014.

Url-16 < *http://www.cns.nyu.edu/david/courses/perception/lecturenotes/depth/depth-size.html*>, date retrieved 4.08.2014.

Url-17 < *http://www.thoughtyoumayask.com/picsbtqq/polarized-3d-images-gallery*>, date retrieved 5.08.2014.

Url-18 < *http://www.businessballs.com/shadow-optical-illusion.htm*>, date retrieved 5.08.2014.

Url-19 < *http://web.mit.edu/bcs/schillerlab/research/A-Vision/A15-2.htm*>, date retrieved 7.08.2014.

Url-20 < *http://brainden.com/afterimages.htm*>, date retrieved 7.08.2014.

Url-21 < *http://www.removethebackground.com/blog/zen-srgb-color-space/*>, date retrieved 7.08.2014.

Url-22 < *http://euler.slu.edu/escher/index.php/File:Necker-cube.svg*>, date retrieved 8.08.2014.

Url-23 < *https://artdocents.wordpress.com/2013/11/12/positive-negative-space/*>, date retrieved 8.08.2014.

Url-24 < *http://brainden.com/line-illusions.htm*>, date retrieved 12.08.2014.

Url-25 < *http://commons.wikimedia.org/wiki/File:Impossible_staircase.svg*>, date retrieved 12.08.2014.

Url-26 < *http://www.wou.edu/~jduchen/cs199/escher_project/biography.htm*>, date retrieved 17.08.2014.

Url-27 < *http://www.pinterest.com/Msartroom/design-gestalt/*>, date retrieved 17.08.2014.

Url-28 < *http://www.world-mysteries.com/illusions/sci_illusions1.htm*>, date retrieved 20.08.2014.

Url-29 < *http://www.world-mysteries.com/illusions/sci_illusions1.htm*>, date retrieved 20.08.2014.

Url-30 < *http://all-that-is-interesting.com/a-camouflaged-chameleon* >, date retrieved 20.08.2014.

Url-31 < *http://gardenofeaden.blogspot.co.uk/2013/11/the-orchid-mantis.html?m=0* >, date retrieved 20.08.2014.

Url-32 < *http://rijksmuseumamsterdam.blogspot.com.tr/2012/01/pere-borrell-del-caso-escaping.html* >, date retrieved 20.08.2014.

Url-33 < *http://www.theguardian.com/science/gallery/2014/aug/05/dizzying-optical-illusions-akiyoshi-kitaoka-pictures* >, date retrieved 22.08.2014.

Url-34 < *http://www.julianbeever.net*>, date retrieved 22.08.2014.

Url-35 < *http://news.blogs.cnn.com/2010/09/09/3d-illusion-in-street-tries-to-change-drivers-attitudes/* >, date retrieved 22.08.2014.

Url-36 < *http://www.oneonta.edu/ /farberas/arth/ARTH209/Parthenon_gallery* >, date retrieved 23.08.2014.

Url-37 < *http://moblog.net/view/295028/building-of-illusion* >, date retrieved 23.08.2014.

Url-38 < *http://www.formfiftyfive.com/2013/12/interview-with-ken-wong-artist-designer-of-monument-valley/* >, date retrieved 23.08.2014.

Url-39 < *http://www.trendhunter.com/slideshow/optical-illusion-interiors*>, date retrieved 25.08.2014.

Url-40 < *http://www.artfire.com/ext/shop/home/GetSweetHJ/28/0/0/*>, date retrieved 26.08.2014.

Url-41 < *http://www.asplundstore.se/products/pov-candle-holder*>, date retrieved 26.08.2014.

Url-42 < *http://www.2222editiondesign.com/BancIllusion.htm*>, date retrieved 26.08.2014.

Url-43 < *http://cargocollective.com/kristinalindqvist/UNGA-KREATIVA-I-RAMPLJUSET-FOR-STBL*>, date retrieved 27.08.2014.

Url-44 < *http://www.zazzle.com/*>, date retrieved 27.08.2014.

Url-45 < *http://www.moillusions.com/hypnose-sofa-illusory-furniture/*>, date retrieved 28.08.2014.

Url-46 < *http://freshome.com/2011/11/21/impossible-triangle-vase-90%C2%B0-by-cuatro-cuatros/*>, date retrieved 28.08.2014.

Url-47 < *http://theawesomer.com/optical-illusion-bookshelf/89745/*>, date retrieved 28.08.2014.

Url-48 < *http://blog.ponoko.com/2008/10/22/aroha-silhouettes-recycled-12-vinyl-jewellery/*>, date retrieved 30.08.2014.

Url-49 < *http://en.wikipedia.org/wiki/Norman_Wilkinson_(artist)*>, date retrieved 10.09.2014.

Url-50 < *http://www.airsoftct.com/camouflage-used-in-connecticut-airsoft/camopatterns2_0/*>, date retrieved 20.10.2014.

Url-51 < *https://www.kickstarter.com/projects/studiocheha/flatlight-candleholder-is-it-2d-is-it-3d-think-aga*>, date retrieved 22.10.2014.

Url-52 < *http://www.houzz.com/photos/188297/Slumped-Glass-Vanity-contemporary-bathroom-sinks-seattle*>, date retrieved 22.10.2014.

Url-53 < *http://www.urukia.com/phantom-table-graft-architects/*>, date retrieved 22.10.2014.

Url-54 < *http://www.nendo.jp/en/works/*>, date retrieved 22.10.2014.

Url-55 < *http://www.nendo.jp/en/works/*>, date retrieved 22.10.2014.

Url-56 <*http://tokyoflashjapan.wordpress.com/2010/09/24/optical-illusion-led-watch-design/*>, date retrieved 25.10.2014.

Url-57 < *http://www.fubiz.net/2014/04/22/shady-illusion-lamp/*>, date retrieved 25.10.2014.

Url-58 < *http://www.dezeen.com/2012/11/02/kishu-by-maya-selway/*>, date retrieved 27.10.2014.

Url-59 < *http://mocoloco.com/vote/good-vibrations-storage-unit-by-ferruccio-laviani/*>, date retrieved 27.10.2014.

Url-60 < *http://designyoutrust.com/2011/10/floating-lamps-by-crealev/*>, date retrieved 12.11.2014.

Url-61 <*http://www.designboom.com/design/puzzle-like-inception-chair-by-vivian-chiu/*>, date retrieved 12.11.2014.

Url-62 <*http://www.madeindesign.co.uk/prod-bottle-holder-chain-pa-design-refpa208.html*>, date retrieved 18.11.2014.

Url-63 < *http://www.design-moderne.com/treasure-mug/*>, date retrieved 18.11.2014.

Url-64 <*http://www.departures-international.com/home/art-and-culture/interviews/use-your-illusion.html*>, date retrieved 20.11.2014.

Url-65 <http://indesignartsandcrafts.com/2012/11/op-art/> date retrieved 18.11.2014

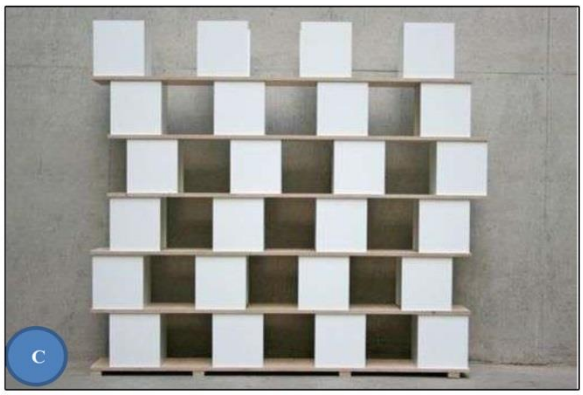
Wall, G. L. (1963). *The Vertebrate Eye and Its Adaptive Radiation*. New York: Hafner.

Weiner, I. B. (2003). *Handbook of Psychology, History of Psychology*. New Jersey: John Wiley & Sons.

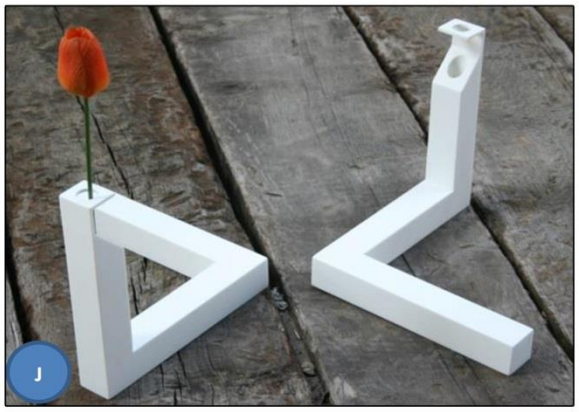
Willis, C. L. (2006). Mind maps as active learning tools. *Journal of Computing Sciences in Colleges*, *21*(4), 266–272. Retrieved from http://dl.acm.org/citation.cfm?id=1127438

APPENDIX 1

Survey's cards




G


J


H


K


I


L

Gender: ☐ Male ☐ Female

Age:

- Arrange these products into three categories below:

1. Appropriation of illusion in design
2. Design inspired by illusion
3. Design creating an illusion

(If you don`t agree with the categories, please define a category which you can include that product.)

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

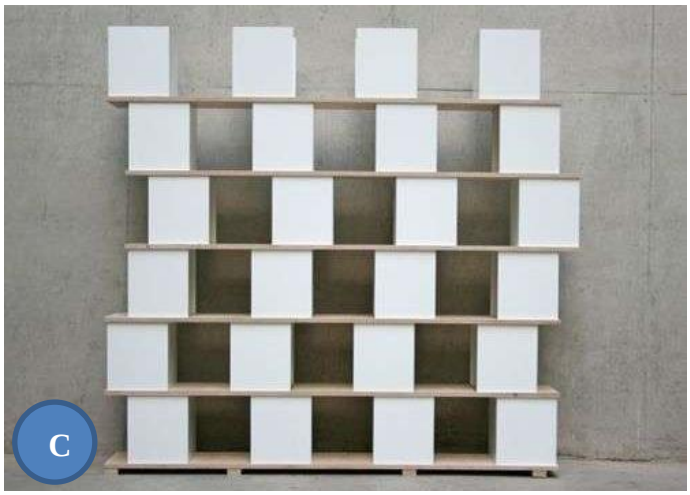
- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives



- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

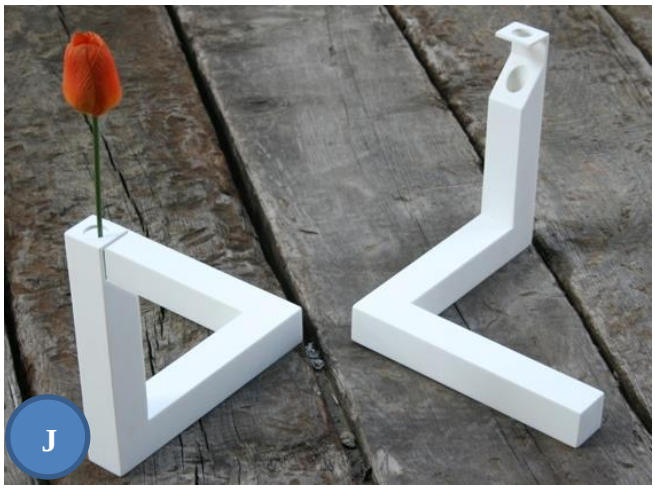
- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives



- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

- Select the category number which you have been choose for this product:
    1. Appropriation of illusion in design
    2. Design inspired by illusion
    3. Design creating an illusion

- Describe the reason of putting this product in the specific group shortly.

- Why do you think that the designer added/used illusion in this product?

- What are the positive and negative aspects of using illusion in this product? (At least on option)

Positives	Negatives

CURRICULUM VITAE

Name Surname: Sina JAHANGIRI

Place and Date of Birth: IRAN, 1981

E-Mail: sina_jahangiri@yahoo.com

EDUCATION:

B.Sc.: Industrial Product Design, Azad University, Tehran-Iran

M.Sc.: Industrial Design, Istanbul Technical University, Istanbul, Turkey

PROFESSIONAL EXPERIENCE AND REWARDS:

- Attended in Red-Dot competition 2011
- Computer ptograms:
  - 3D studio max: Modeling, Rendering, Texture, Lighting, Animation and Simulation but highly experienced in Modeling and Animation
  - Rhino: Modeling, Rendering, Texture, Lighting
  - Z-brush: Modeling
  - Flush: Animation, Web and multimedia Designing
- Languages:
  - English
  - Turkish
  - Azari
  - Persian
- Artistic skills
  - Sketching and Rendering
  - Modeling and making Maquette
  - Painting
  - Photography