

**An Exploratory Approach of Developing Visually Appealing Furniture Design  
Concepts by Employing Psychological Effects**

by

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## **Abstract**

The conscious application of perceptual psychology in furniture design has not been fully explored in shaping user experience. The psychology of perception involves cross-disciplinary applications. Despite extensive research on the use of perception, designers still lack a systematic approach to extend design inspiration in the field of furniture design. The application of perception involves many fields, but how to combine these technologies with furniture design still needs to be explored.

This study addresses this gap by proposing an exploratory framework that systematically utilizes psychological effects to produce visually compelling furniture concepts. Analyzing the principle of perception combined with perception of furniture design will allow the development of guidelines that will aid in the design and understanding of furniture that utilizes the principles of perception. Doing so will help designers move from emotional selection and analysis to prototyping. The analysis of the perception principle helps the designer to extract the elements that play a role in different perceptions and combine them with the characteristics of the furniture. In the guidelines, a set of concrete design schemes is proposed. Using this process, the designer can specify the design by the desired effect, allowing the designer to fully explore the application of perceptual psychology in enhancing visual appeal.

This study hopes to provide practical exploration methods for designers that enables designers to go beyond traditional design themes and add design inspiration for the perception aspect. The guidelines allow designers to effectively combine psychology with furniture and explore eye-catching furniture designs. By connecting cognitive psychology and industrial design, this work demonstrates the transformative potential of perception as a

scaffold for innovation, a paradigm shift from traditional design thinking to perception-driven furniture design.

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## **Chapter 1 Introduction**

### 1.1 Problem statement

In the modern era, furniture designers face the difficulty of finding inspiration for furniture design. Although many pieces of furniture have diverse design styles, those choices tend to focus on improving design by integrating different cultural and modern elements. Increased automation and productivity accelerated the standardization of furniture designers. However, the field of perceptual psychology and historical perceptual principles provide an opportunity for designers to broaden their design inspiration.

From ancient times, artists and architects have used perceptual principles to produce illusory effects. Since the Industrial Revolution, many theories and research on perception have emerged, allowing artists and architects to enhance visual effects in their work. Similarly, the field of perceptual psychology has a significant potential to enhance visual impact in furniture designers. However, at present, few effective methods exist that can help designers combine effects generated by different perceptual principles and illusions with furniture design. Therefore, this project researches historical perceptual effects, perceptual psychology, and their applications to develop a set of guidelines that allow designers to use these insights with their furniture designs.

## 1.2 Need for study

As noted in the previous section, designers lack effective methods to incorporate perceptual principles into furniture designs. Although these insights are successfully applied in many fields, designers must resolve several challenges. Essentially, designers must consider the practicality of the final furniture design and the feasibility of integration of perceptual principles with design. These challenges are described below:

1. The balance of the integration of perception and furniture: How to appropriately apply perceptual principles in furniture design while maintaining the functionality of furniture as a commodity is a complex design challenge.

2. Limitations of perception application: Many perceptual elements and illusions encounter effect degradation when dealing with 3D designs. These may lead to an unremarkable perceptual effect.

This study provides a set of design guidelines to help designers quickly screen available perception methods, extend the selected perceptions to the design ideas of furniture, and make the design of furniture more visually attractive. This process can not only help designers enhance their understanding of perception, but also enable them to gain more design inspiration.

The results of this study will provide practical guidance for designers, and at the same time offer emerging design perspectives for furniture design, promoting the development of design inspiration.

### 1.3 Objectives of the study

Purpose of this thesis include: :

1. Establish a systematic design guideline to assist designers in better incorporating perceptual effects as design inspiration into contemporary furniture design This includes the analysis of perceptual principles, classifying them and how to utilize them effectively in furniture design.
2. Through classification, perceptual processes are filtered into different realizations which help designers determine the perceptual usage methods they might apply in the early stage.
3. Provide research on perceptual effects and the necessary conditions for achieving results in order to . Help designers avoid design conflicts and mistakes that lead to reduced effects, therefore Obtaining a more flexible application of perceptual principles and Maximizing their effect in furniture design.
4. Provide guidelines for the transformation of design elements between perceptual principles and furniture design to help designers transform usable elements of those concepts into the design language of furniture. Doing so will let designers understand what perceptual elements can be integrated into components of furniture. Designers will be able to refer to these guidelines and draw inspiration.
5. Provide actual design plans for reference, which will help designers with exploration and reference. These plans will show how different perceptual effects can be effectively used in different furniture.
6. Provide an explanation of challenges in using perceptual elements n in furniture design, which will help designers avoid ineffective results By achieving these goals, this study will provide designers with practical design tools and methods, helping them effectively utilize perceptual effects in furniture design and expanding their design inspiration and thinking.

## 1.4 Assumptions

The following assumptions were made in this study:

- It is assumed that designers interested in this study are those with basic knowledge of furniture, including materials, design, and manufacturing.

- It is assumed that designers who have done furniture are looking for ways to enhance their designs.

- It is assumed there is an interest in designing furniture with a focus on the perceptual domain.

- It is assumed that perception theory has the potential to be redesigned: different perceptions can be adapted and combined in a way that is effective in furniture design, retaining the perceptual effect while ensuring the practicality of the furniture.

- It is assumed there is a demand for different furniture designs in the design market: It is likely that consumers are willing to accept and appreciate furniture designed through the application of perceptual theory that allows for more interesting culturally appropriate designs.

- It is assumed designers are willing to accept and apply new methods: Designers who wish to reach consumers with a desire for furniture that is not purely functional are willing to accept and apply the design guidelines proposed in this study.

## 1.5 Scope and Limitations

### Scope:

-Selection of Perception Types: this study focuses on several representative perception principles. These principles are chosen for their strong visual impact and potential application.

-Design application areas: the study focuses on how the effects of perceptual principles are applied to furniture through design principles. These effects were chosen because of the high degree of integration of their basic principles with furniture.

-Research methodology: this study will use the research method of inquiry. The basic requirements of specific perceptions are provided. The designer combines the analysis of such requirements and characteristics with different features of furniture. This study aims to provide practical design principles and inspiration for designers.

### Limitations:

-Limitations of perceptual requirements: although the perceptual focuses selected in the study are representative, it is not possible to apply these principles in design without constraints. Different perceptual effects have different heuristics. These rules have specific requirements and scope of application. Therefore, some perceptual theories may not be fully applicable to all designs of furniture.

-Limitations of perception studies: although the selected perception approaches can provide specific references and inspirations, perception is somewhat subjective. The actual result may not be the same as the preconception. Adjustments need to be made to take into account the specific context in which they are applied in practice.

-Limitations in terms of effect: Some perceptual effects are proposed in 2D, which may lead to a decline in effect when applied in 3D. Some perceptions may be valid from the

perspective of approximate surfaces. Or rather, from a perspective close to 2D presentation..

Some color class perceptions that require high contrast may be interfered with by shadows in practice, resulting in a decline in effect.

## 1.6 Anticipated Outcomes

-Effective application of design guidelines: This study will help designers quickly find the perceptual design methods they want to use through a systematic set of design guidelines, and better apply perception as a new design inspiration effectively in furniture design.

-Acquisition of perception methods: Through design tools, designers can better understand and apply perception to make furniture design more visually appealing and broaden their knowledge and thinking in the field of perception.

-Expansion of design ideas: This study will provide designers with design tools and some design references To enhance the inspiration of designers during the design process. Doing so will open up a brand-new design idea for some designers and help them expand their design concepts and methods and obtain references and inspirations from the design guidelines.

-Exploration of perception research: This study will provide designers with a starting point for design ideas regarding perception effects to provide a design thinking direction to help future designers continuously explore and innovate on the path of perception.

## 1.7 Definition of Terms

Perception: It refers to the reaction of thought. This is a rational and conscious way of experiencing the reaction after objective analysis through thinking in order to Reach an opinion on something through analysis. Perception is influenced by our existing knowledge, experience and way of thinking.

Sensation: It refers to the reaction of the body. This is an emotional or subjective judgment that includEs vision, hearing, smell, taste, touch, etc. It is the simplest and most basic form of reflection (Spielman, 2020).

Visual illusion: A visual illusion is a perception that differs from reality, characterized by the visual perception seeming to be different from the actual situation. It is caused by the way our brains process visual information. These illusions can reveal how our visual system interprets the images we see, sometimes even misinterprets them (Bach, 2006).

## **Chapter 2 Literature Review**

### 2.1 Introduction to Literature Review

This chapter will understand the development of perception by studying the application of perception in history. Secondly, this chapter will also help readers understand some commonly used theories in perception through the research of some perception theories and principles. Through research, it is explored whether there is an opportunity to make perception a way of furniture design and to make furniture more visually attractive through perception.

Perception is in some ways self-inflicted by the person. It is the process by which an individual receives external stimuli through the sensory system and processes them into concepts that are meaningful to him or her. In psychology, it is defined as the ability to organize and interpret sensory information into structured objects and events (Fish, 2021). If we use this process for vision, we will have an illusion.

A perceptual misdisplay is an illusion. Illusion is a manifestation of the perceptual system's ability to predict the world based on experience. Illusion reflects the brain's best guess of future sensory input based on past experience, not error. People do not passively receive visual input but actively interpret the phenomena they observe, Similar to the process of perception. In this process people use their knowledge to help them understand. But in many cases the truth is not what one thinks it is. An illusion is then created. These errors are often due to experience or knowledge being misinterpreted (Gregory, 1997). When perceptions are based on interpretations made by the brain's sensory input and knowledge, illusions are the result when that interpretation goes wrong. This approach suggests that people give their own interpretations of certain phenomena through their own brains. If this thought process is utilized, intentionally designing things to make people think incorrectly, designers can produce a different effect.

As a psychological process by which humans interpret and organize environmental stimuli, perception has been a key factor in architecture and art design throughout history. From the use of height to enhance the sense of sanctity in Gothic churches, to the establishment of linear perspective during the Renaissance, and then to the explosive development of modern perception, perception has extensively created people's experiences of space and form (Arnheim, 1954; Gombrich, 1960). The field of art also makes full use of perceptual mechanisms such as visual illusions, color contrasts and the relationship between the image and the background to trigger emotional and cognitive responses from the audience (Gregory, 1997).

Although perception theory has a profound and continuous application tradition in architecture and art, in the field of furniture design, its application is relatively scattered and lacks systematic discussion. Although perception has developed explosively in modern times, the correlation between the development of furniture and perception has not increased. As an important tool for contact with people, the design of furniture should also pay attention to the influence of vision and perception. However, compared with the application of perception in architecture and art, the conscious use of perception effects in furniture design is relatively rare in historical literature, and related research is also limited.

Based on this observation, this paper aims to review the historical application examples of perception principles in architecture and art design through literature review, explore the potential application possibilities of these principles in furniture design, and provide a new perspective of perception psychology for furniture design research.

The literature will cover two major aspects:

First, regarding the application of perception in history. This part will be to illustrate that perception did not emerge out of thin air in human history. It has a long history of use. People have consciously utilized perception to achieve certain visual effects since a very early time.

We will follow the trajectory of history to explore how these perceptions have been utilized and developed throughout human history.

Second, describe some important perception theories which include Gestalt psychology, visual focus, and the illusion theory in terms of color. This part is designed to enable designers to better understand related important theories other than the perception effects that will be mentioned in the design tools in order to help designers understand the reasons for the formation of some perceptions.

## 2.2. Historical background: the combination of psychology and design

Perception is neither a mysterious theory that emerges out of thin air nor an unknown magical phenomenon. It has been deliberately utilized by humans throughout recorded history. There are many classic cases of art and architecture that deliberately use perceptual effects. This section highlights the trajectory of perceptual effects in history.

### 2.2.1. Ancient times

The application of perception in design can be traced back to the ancient Greek and Roman periods. In an early stage of civilization, perceptual principles have already been utilized as a visual tool. This section will discuss how the early methods of perception were used to influence people's vision during these historical periods from ancient Greece and ancient Rome to the Renaissance.

The pursuit of visual perfection led architects and sculptors to investigate how to optimize the viewing experience through visual illusions. Ancient Greece stands out as an important period of civilization. The art and architectural works of this period provide the earliest examples of utilizing the principles of perception to improve design, and are an inescapable starting point in the history of illusion design.

The use of perception effects in the Parthenon is an example of ancient architectural psychology at its best. The architects countered the natural limitations of the human eye with precise curves, creating the illusion of seeming perfection with artificial calculations that are actually imperfect. To make the temple look perfect, the architect built the temple imperfectly.

The base of the temple was not designed as a horizontal straight line. Instead, it was designed with a curved bulge that is difficult to see with the naked eye. The pillars of the temple also appear to look vertical, but they are actually built with the sides facing inward. The advantage of this is that the building only seems straight when the observer looks at the bottom of the building. In addition, the sides and back of the building have been amended in the same way so that the surface of the base of the Parthenon is raised upwards in the center of the building (Leonard , 2018).

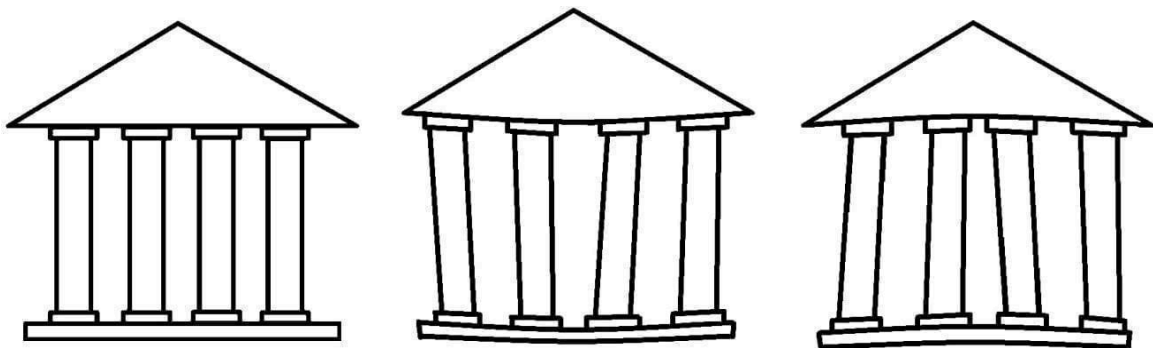


Figure 2.2.1 An illusion of the construction of the Parthenon Temple (Ernt, 2021).

The columns are the centerpiece of the temple. The columns slope inward towards the center of the building. The corner columns are also slightly thicker than the other columns and closer together than the neighboring columns. This allows the corner pillars to have less spacing between them and the pillars closest to them than the spacing between the other pillars (Ernt, 2021), as seen in Figure 2.2.1. The left side is what the observer sees. In the

center is what it looks like as observed for the use of the illusion. The far right is what the temple actually looked like after using the illusion. By artificially employing the illusion, the temple was made more grandiose compared to the regular construction scheme.

Roman mosaics are an important example of perception being used as an ornamental design on a plane. One example is the mosaic pattern in Figure 2.2.2 that uses different colors to express the color changes of objects under different light and shadow effects. The advantage of this is that people can create a three-dimensional effect on a two dimensional plane. This can show the spatial relationship of patterns (Gombrich, 1960). The picture in Figure 2.2.3 can better show this feature. Viewers can see the direction of light irradiation due to different colors. This choice makes the pattern appear three-dimensional.

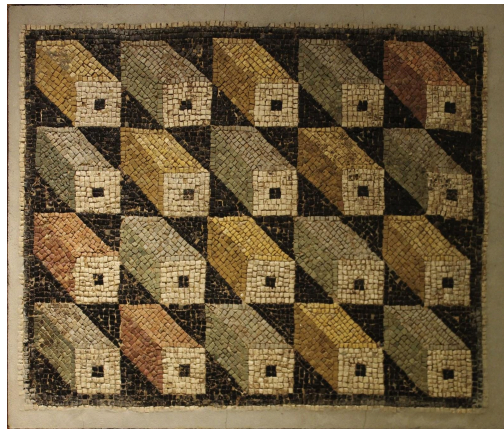


Figure 2.2.2 Roman cuboid mosaics 2nd centuries A.D



Figure 2.2.3 Roman cube mosaics 2nd centuries A.D

Architecture developed to a certain extent during the Roman period. In the dome of the Pantheon, Figure 2.2.4. many concave shapes were designed. These concave shapes somehow make people feel like the air is being pushed outward so it feels like the space is expanding outward (Arnheim, 2004). Through this inwardly concave design, when applied to buildings such as the Pantheon, the numerous concave walls allow people to feel that the internal air is being squeezed outward. This can make people feel an expansion from the inside out and help expand the indoor space.



Figure 2.2.4 Pantheon, 27 B.C.

During this period, all disciplines are at the primary stage. There is no complete system of research to support the influence of perception and visual illusions. But people used effects of perception in the process of intentionally presenting things in a perfect state.

### 2.2.2 Middle Ages

With the advent of the Middle Ages, human beings have achieved more development in the field of architecture. Due to the expansion of Catholicism, cathedrals developed significantly in the Middle Ages. As one of the visual methods used in architecture in the classical period, the use of perceptual effects gained more possibilities for application along with more architectural developments.

During the medieval period, many cathedrals were designed and built as the highest achievement of human creations of the time. There was no shortage of some of the principles of perception utilized by the designers. The Rose Window is one of the symbols of Notre Dame de Paris. This window always gives a feeling of soaring upwards or surfacing. As shown in Figure 2.2.5.,if the main body of the building is divided into two, one would naturally feel that there should be enough gravity at the bottom so as to achieve balance. So people will mark the bottom of this division line. The bottom is more important than the top in people's perception of gravity. But the Rose Window is just above the center. This design puts the rose window in a position of lightness (Arnheim, 1972). This design gives the Rose Window a perception of rising upwards. This is the sense of ascension that the church wants people to have.

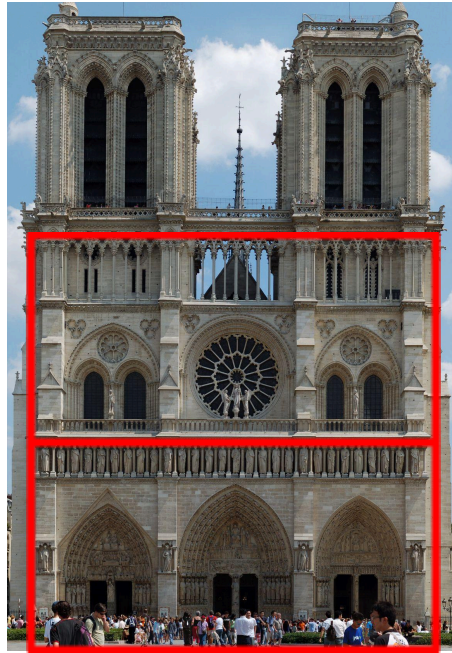


Figure 2.2.5 Notre Dame de Paris, 1260

Another famous building is Chartres Cathedral. Its design not only made a breakthrough in architectural technology, but also profoundly reflected the intuitive application of psychological principles, especially the understanding of spatial perception. By skillfully using the design of height, Chartres Cathedral has greatly influenced the perception, emotion and religious experience of believers.

This Gothic building greatly enhances the sense of space height by using extremely high vaults and pointed arches. This design makes the interior of the church more magnificent and solemn by lengthening the vertical space. As Frankl (1962) pointed out, "By vertically pulling up the space, the designer has successfully created an awesome sense of loftiness, making believers feel their own smallness and the greatness of God, and enhancing their religious experience" (p. 112). This vault design makes the interior of the church look extremely magnificent, guides the believers to look upward, and makes them feel their own smallness and the greatness of God, thus deepening the religious experience.



Figure 2.2.6 Chartres Cathedral Interior of Chartres Cathedral, France.

Through the Middle Ages, the application of perception developed in the field of architecture. Due to the spread of religion and the construction of cathedrals, people made more and more use of perceptual principles. However, during this period, there were still no signs that the field of perception received systemic explanations and theoretical support. The use of perceptual effects is more like a way to present things as "perfect".

### 2.2.3. The Renaissance

The Renaissance was a turning point in the combination of psychology and design. Artists and architects began to systematically study how to influence people's perception and emotional experience through design. Marking the combination of science and art, designers and artists began to consciously use psychological principles to influence the audience's visual perception, emotional response and spatial experience.

The artistic application of perspective technology during the Renaissance witnessed tremendous innovations. In the early 15th century, the Italian architect Filippo Brunelleschi initiated the linear perspective method through experiments (1415-1420), establishing

mathematical rules to construct the precise representation of three-dimensional space in a plane. Linear perspective, pioneered by Brunelleschi, has been widely used in architectural design. This technique is considered one of the most important breakthroughs in the history of art and architecture. The technique combined mathematics with visual perception for the first time, allowing artists to create a realistic three-dimensional sense of space on a two-dimensional plane. This principle has had a profound impact on human perception of space and is widely used in architecture and painting (Zucker, 2015).

The linear perspective maps the three-dimensional space to the two-dimensional picture through the fixed vanishing point and horizon line, as shown in Figure 2.2.7. This method emphasizes the central symmetry and focal unity of the composition, forming the geometric logic of space. Doing so makes the viewer feel the realistic depth of space from a specific point (Wittkower, 1953). This perspective is not only a painting technique, but also a spatial idea integrated with the proportional structure of Renaissance architecture.

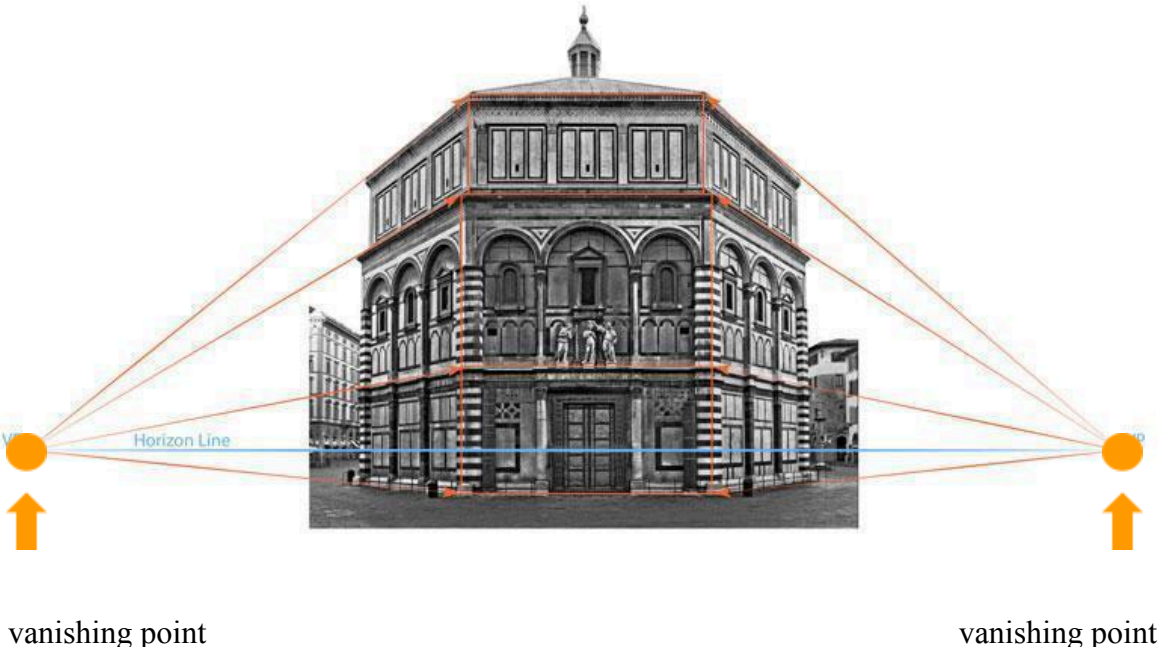


Figure 2.2.7. Filippo Brunelleschi, *Florentine Baptistery* (Brunelleschi, 1410)

Leon Battista Alberti systematized this theory in his 1436 work *De Pictura* (Figure 2.2.8), establishing the perspective criterion of Western painting for five hundred years and enabling artists to achieve spatial depth and realism through geometric principles. The handling of perspective was the most influential among all his suggestions and influenced the entire Italian Renaissance period (Ackerman, 1994)

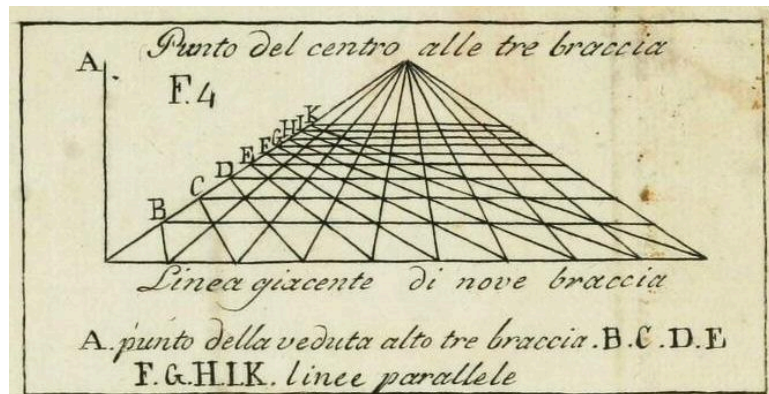


Figure 2.2.8. Alberti, *De pictura*. (Alberti, 1804)

Pierre de la Francesca's *The Brera Madonna* (Figure 2.2.9) from 1472 to 1474 innovatively coincided the vanishing point with the center of the figure's face, aligning the vertical axis of the shell's suspended egg with the horizon and endowing the spatial position with symbolic meaning.

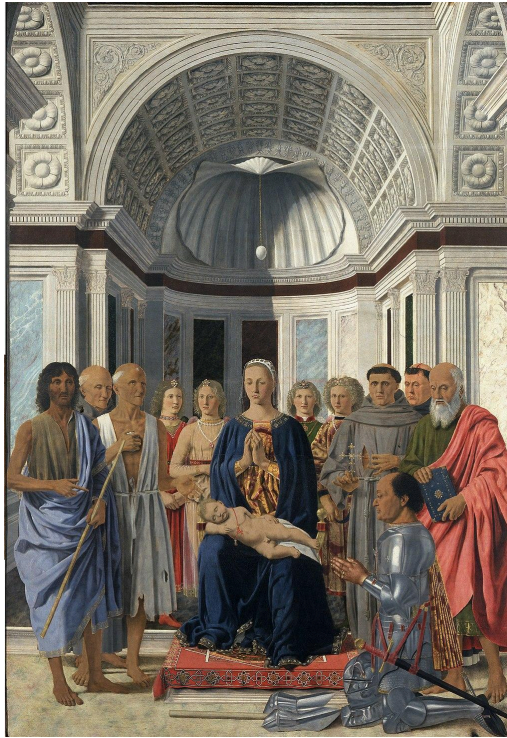


Figure 2.2.9. Piero della Francesca, *The Brera Madonna*, 1472

Masaccio's *The Trinity* created in 1425 was the first to integrate perspective with architectural structure, enhancing the three-dimensional illusion through the visual integration of fictional vaults and the real scene of the church (Pastor, 2005). Masaccio's use of linear perspective in *The Trinity* creates a seemingly realistic vaulted space that marks the Renaissance's exploration of spatial illusion (Gartner 1998, p. 25.). As shown in Figure 2.2.10, the scattered lines of the vault meet at the beginning of Christ in the center of the composition(Orange line).



Figure 2.2.10. Masaccio, The Trinity painting, 1427

This technique is also widely used in painting. In Da Vinci's *The Last Supper* (Figure 2.2.11.), the artist uses linear perspective to direct all eyes to the Jesus in the painting, enhancing the sense of focus and depth of vision. "Through clever perspective, Da Vinci guides the visual center to the head of Jesus, creating a strong religious atmosphere and enhancing the emotional engagement of the viewer" (Kemp, 1990, p. 78). The perspective lines converge in the center of the picture, and the significance of the picture lies precisely in the position of Jesus.

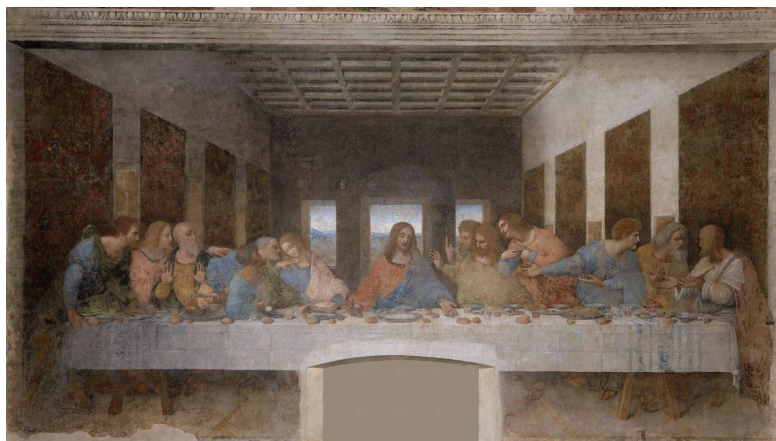


Figure 2.2.11. Da Vinci's The Last Supper

Perspective was an important theoretical basis of the understanding of perception during the Renaissance. It is also an important breakthrough in the theory and academia of perception. People began to discuss perception from a tool for use into an academic theory. Although perception still existed as a tool to make things appear perfect, scientific perception was an important theoretical beginning.

#### 2.2.4 Modern times.

With the advent of the Industrial Revolution era, human productivity and technological levels reached an important period. Machines began to replace human labor. Advanced instruments have increased the ways for humans to explore the world. Human beings began scientific development in all fields, including that of perception.

In the 19th century, significant progress was made in the research of visual perception. Many scholars successively proposed different theories of visual illusions. These visual illusions will become the main usage methods of design tools.

Among them is Hermann von Helmholtz's (1821-1894) Helmholtz illusion. Louis Albert Necker (1786-1861) was famous for the Necker cube; Johann Christian Poggendorff (1796-1877), the Poggendorff illusion; Ernst Mach (1838-1916), famous for the Mach Belt; Franz Karl Mailler-Lyle (1857-1916), famous for the Mailler-Lyle illusion; And Mario Ponzo (1882-1960), famous for the Ponzo illusion (Wade, 2018).

These theories of visual illusions are different from previous perceptual principles. These theories are all limited to demonstrating the most intuitive perceptual effects. Previous perception effects had all been used as tools to create "perfect" things. These new theories were proposed as the simplest and most intuitive display method of visual illusions. Such development has led to the diverse growth of perception theories.

The principle of perception has been applied for quite a long time. In the application of these principles by humans, it has evolved from the early pursuit of perfect visual presentation effects to systematic research. During the Industrial Revolution, various theories of visual illusions emerged from the study of perception. In addition, perception, as a tool of visual design, was gradually applied to products with greater entertainment value.

The Ames Room was invented by American scientist Adelbert Ames Jr. The Ames Room is one of the most classic spatial visual illusion experiments in psychology and architectural design. When people observe the Ames Room from the void, the room looks like a normal rectangular space (Figure 2.2.12). But when two people stand in the two corners of the room respectively, their body shapes will appear to change. The person in one corner looks taller than the one on the other side. When their positions are swapped, the appearance of their body shapes will change again.

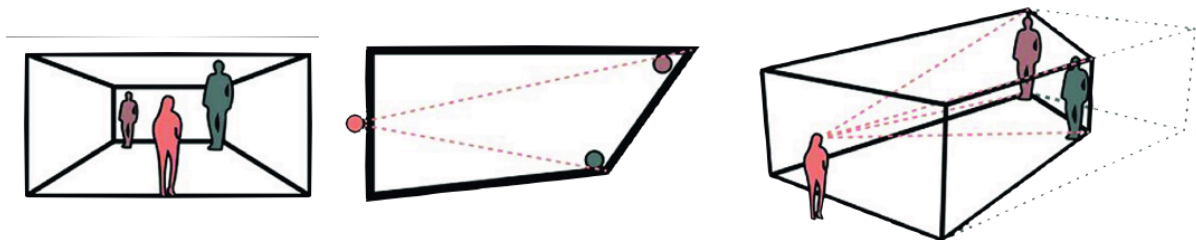


Figure 2.2.12. Ames Room , Adelbert Ames Jr. (Adelbert, 1940)

The geometric shape of the Ames room has been meticulously designed. The principle of perspective is applied to alter the geometric structure of the space, deceiving people's depth perception system and creating the illusion that people suddenly become larger or smaller. The human visual system usually maintains the shape of an object unchanged, even when observed from different angles. However, under the special structure of Ames Room, visual

cues are distorted, and human cognition of three-dimensional space is more likely to be affected by false information, resulting in the brain's inability to correctly restore the spatial shape (Dorward, 1997).

Athens Ames room is quite different from a normal room, but it can be compared with the previous cathedrals built using perception principles. However, it is more inclined towards entertainment in terms of visual effects. In the field of art, there are also artists willing to use perception principles to create paintings that are different from those of the Renaissance.

Maurits Cornelis Escher created a distinctive art by using perception principles. Multiple effects are used in the picture Sky and Water (Figure 2.2.13). The law of Figure-ground from Gestalt psychology reveals the ambiguity of visual perception and classification. Escher designed two shapes with closely joined contours. When the viewer's focus is shifted within the same image, the "figure" and the "ground" keep switching, creating the illusion of a double interpretation. Viewers experience the fluidity of the image's transition between the "positive and negative" characters, enhancing the mystery and sense of participation in the work. The geometric factors in the image, including convexity, similarity and color uniformity, adopt the Continuity and Closure principle of Gestalt psychology. Through continuous contour lines and the "uncompleted closed" structure, the audience is induced to automatically complete the image. It enhances the efficiency of shape recognition, enabling the audience to quickly interpret the content of blurry or abstract images (Lin, 2018).

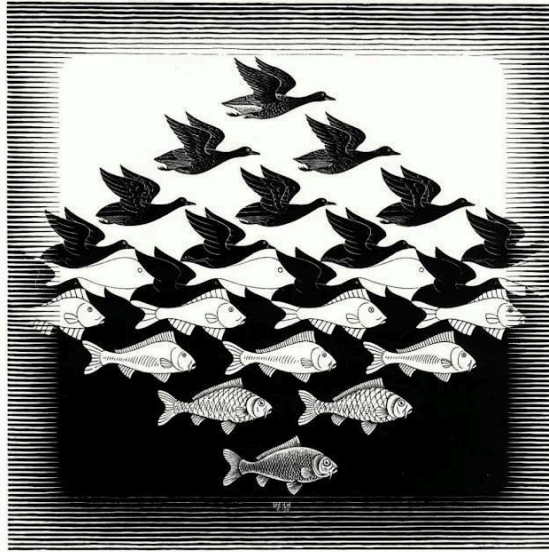


Figure 2.2.13 Escher, Sky and Water, Woodcut, 1938 (Olsen, 2013)

Human beings have a long history of exploiting illusions to achieve good visual effects. Besides using an understanding of perception to make construction more harmonious and art more in line with perspective, there are other possibilities for humans. With emerging theories and the development of science and technology during the Industrial Revolution, many perceptual principles were used as pure visual effects. People obtain interesting visual presentation methods through these perceptions. Therefore, both construction and art have been liberated from the previous purpose of perceptual use as a means of presenting perfection to instead develop in a more entertaining or interesting direction.

### 2.3 Some Theories and Principles of Perception

Since the Industrial Revolution, some theories of non-visual illusions in the field of perception have developed. These theories, as a collaborative effort, help people understand the operation mode behind some perceptions as the research on perception became more and more detailed. These principles and theories include Gestalt psychology, focus, sense of order and Lateral inhibition. These perceptions are not as obvious as other illusions. But behind the

scenes, deficiencies also affect people's understanding of the observed objects. Because these theories and principles are several of the more common and important ones in the field of perception, they can help designers obtain more inspiration.

### 2.3.1 Gestalt psychology

Although Escher never received formal psychological training, it was still possible for him to create works with perceptual effects. In order to gain an in-depth understanding of how these works influence the audience, it is necessary to turn to the theoretical basis behind it - Gestalt psychology. This school of psychology emerged in the early 20th century; the organizational principles it proposed provide a systematic explanation for the relationship between image structure and perception, and also lay a theoretical foundation for the perceptual effect of Escher's works.

In the modern period, the research of psychology became more systematic and specific. At the beginning of the 20th century, a German school of psychology pioneered Gestalt psychology. This academic field emphasizes the wholeness in the process of human perception and cognition, and holds that human beings tend to organize visual information into meaningful whole rather than isolated fragments. The word (Gestalt) means "shape" or "form" in German. The core idea is that the whole perceptual experience is not a simple sum of all parts, but is integrated through unique organizational principles (Koffka, 1935).

Max Wertheimer is considered one of the founders of Gestalt Psychology. He put forward the basic idea of the school of thought by studying perception of movement. Wertheimer's research on the Phi phenomenon is very famous. Basically, when two stationary objects appear alternately in the visual field, people will perceive continuous motion, even if no motion actually occurs. Through the study of this phenomenon, Wertheimer pointed out that the human perceptual system does not simply splice and react to external stimuli, but

automatically organizes these stimuli to create a whole perceptual experience. This shows that the whole model in the process of perception is better than the isolated part (Wertheimer, 1938).

Gestalt psychology puts forward a series of principles of perceptual organization, which describe how human beings automatically integrate sensory input information into a meaningful whole. These principles are explained below:

**Law of Proximity:** When objects are close to each other in space or time, they are often perceived as a whole.

**Law of Similarity:** Visually similar objects (such as the same color, shape or size) will be preferentially organized together to form a whole.

**Law of Continuity:** When objects are arranged along a continuous path, people tend to regard them as a whole.

**Law of Closure:** Even if objects are incomplete, the human brain tends to automatically fill gaps and perceive them as complete shapes.

**Law of Common Fate:** Objects that move or change in the same direction will be regarded as the same unit.

**Law of Symmetry:** Symmetrical elements are more likely to form figures than asymmetrical elements and are perceived as a stable whole.

**Figure-ground:** In any visual scene, we will automatically distinguish between "Figure" and "background" (Koffka, 1935; Wertheimer, 1938).



Figure 2.3.1. Cydonia, Viking 1, NASA - (Viking 1, 1976)

The famous Face on Mars "Cydonia" (Figure 2.3.1) was captured by NASA's Viking 1 probe in 1976. This "face" is actually a visual illusion caused by a pile of natural rocks on Mars. The reason why people recognize it as a human face is that humans prefer to organize information in the simplest and most stable way, known as the Law of Pragnanz perceptual system in Gestalt Psychology. The result of the "Martian face" is that humans have simplified complex landforms into the highly familiar pattern of "human faces" because it conforms to the brain's archetypal memory of "facial features" (Kanizsa, 1979).

People will separate human faces from other things, a process known as the Figure-Ground Relationship in Gestalt Psychology. Visual scenes are divided into the foreground (figure) and the background (ground), and the two cannot dominate perception simultaneously. This concept applies to the Mars Face: When the human brain recognizes the rock structure as a "face" (graphic), the surrounding landforms automatically recedes into the background. Conversely, if the focus is on geological features, the perception of "human faces" disappears

. The face in the photo is not very clear. However, according to Gestalt Psychology's Law of Closure, the brain tends to transform incomplete visual information into complete graphics. The perception of the rocks as the Mars face relies on the shadows and broken contours of rocks to form local lines similar to eyes, noses and mouths. Although the actual structure is not coherent, the brain automatically "closes" these fragments to construct a complete human face. So, even if there are gaps in the figure, the observer will still perceive it as a closed whole (Koffka, 1935)

Gestalt psychology is also used in architecture. For example, Arnheim discussed the use of the "graphic-background" principle on windows. He described the earliest window as a hole in the wall. It creates a visual paradox. If we regard the wall as a foundation, then the window is regarded as a figure because its edge is very thin. This makes this wall an image. The window becomes a hole (Figure 2.3.2 a). One way to solve this problem is to add a lintel to the window (Figure 2.3.2. b). This affirms the graphic characteristics of the window and separates the graphic from the substrate. Another way is shown in Figure 2.3.2.c. The area of the window has been expanded, which makes the wall look like a boundary. The window has become the "bottom". This example indicates that Gestalt psychology can also be applied in architecture.

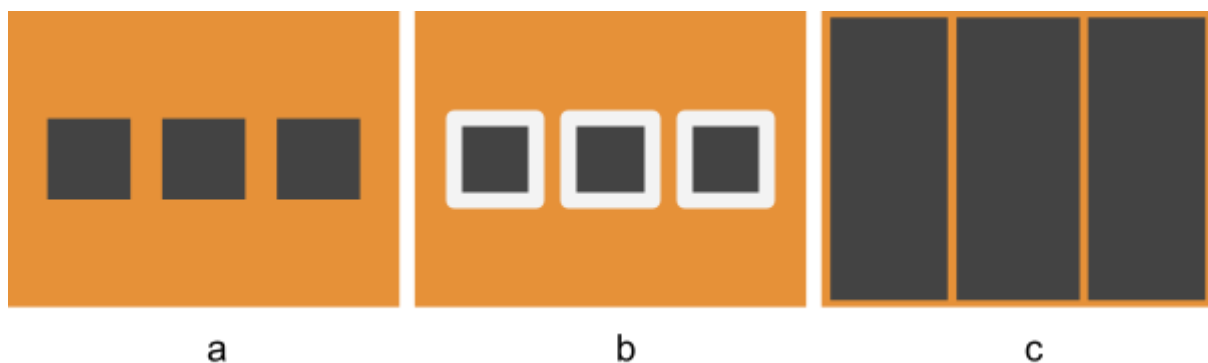


Figure 2.3.2. Windows

Gestalt psychology, as one of the most important theories in modern times, can be rationally utilized in art and architecture. This theory helps people study perception to explain and understand some perceptual phenomena. Gestalt psychology has significant potential in the application of perception effects to furniture design.

### 2.3.2 Sense of Order

Sense of order, an important part of the human cognition and perception system, refers to people's organizational and structural tendencies towards vision, space and information. This section explains key elements of this perceptual sense.

In *The Sense of Order*, E. H. Gombrich (1979) discussed in detail the influence of sense of order on human psychology and perception, especially its importance in art and decoration. The sense of order has a profound impact on human beings because it can help the brain simplify complex visual information and provide aesthetic satisfaction and cognitive stability. Gombrich mentioned that the influence of order is not only reflected in the aesthetic experience, but also related to how our brains process information: "A sense of order can reduce the cognitive burden, because it allows us to simplify the complexity of the world by recognizing patterns" (p. 13). He believed that order provides a structured framework that enables the human brain to organize sensory input more efficiently.

A sense of order can also affect our mood. Gombrich (2017) wrote: "When humans are confronted with a disordered environment, they will experience anxiety. On the contrary, people will feel safe and relaxed towards an orderly structure" (p. 67). Through a sense of order, individuals can find stability and predictability from the chaos of the external world, which brings a sense of balance and control to psychological well-being.

We can observe relevant applications from some modern buildings, such as the *Memorial to the Murdered Jews of Europe* (Figure 2.3.3), a monument built in Berlin to commemorate

the Jewish victims of the Holocaust in Nazi Germany, designed by architects Peter Eisenman and Bro Hapold. The memorial tube is covered with 2,711 concrete slabs or "stone tablets", a memorial hall composed of numerous gray cuboids of similar length and width. Numerous grey squares form a whole. The orderly grey structure creates a sense of loneliness and powerlessness (Emcke, 2005) Wolfgang Thierse, the President of the German Bundestag at the time, described this monument as one that enables people to understand "what loneliness, powerlessness and despair mean" (Brody, 2012).



Figure 2.3.3 *Memorial-to-the-Murdered-Jews* by Buro Happold / Piotr Dziubak



Figure 2.3.4 Fork illusion (Gombrich ,1979)

Gombrich (1979) also mentioned the Tuning Fork illusion (Figure 2.3.4), which is a geometric illusion and often misunderstood visually as a continuous trigeminal object. He

pointed out: "The visual illusion of a tuning fork depends on our basic perception tendency of the shape of an object, and the brain will automatically fill and simplify the shape we see, leading to our misunderstanding of its structure" (p. 237).

### 2.3.3 Focal point

The principle of "the whole is better than the parts" in Gestalt psychology also explains why attention is concentrated from the external whole structure to the internal details.

Wagemans et al. (2012) pointed out that "when the visual system deals with complex scenes, the overall features of the periphery first attract attention, and then the attention gradually moves to the local features of the interior to further analyze the visual information" ( p. 1182). This shows that the human visual system organizes and integrates visual information from the whole to the part and from the outside to the inside.

The edges are key areas of shapes we look at. Many objects are designed in a more elaborate way at the edges, as in Figure 2.3.5, the Persian carpet. The edges of the carpet have a more subtle and intricate pattern. This is because we look at the picture from the outside looking in. The edge of the pattern is the part that best expresses the characteristics of the pattern (Gombrich, 1994). We prefer screens with narrow bezels for the same reason. Our focal point is the edges, so our view will start from the edges.



Figure 2.3.5 Persian Qum Rug

In *The Sense of Order*, E. H. Gombrich (1979) discussed visual focus in architectural design, especially the Roman column (Figure 2.3.6) and its influence on the audience's attention. He mentioned: "When our eyes are scanning the Roman column, we will find that most of our attention is focused on the junction between the column and the top. This is because visually regular things can produce a 'read' psychological effect, prompting us to pay more attention to the ending point or change of the pattern " ( p. 177).

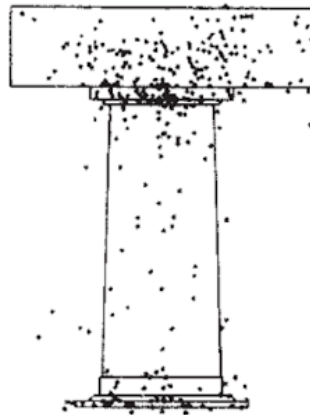


Figure 2.3.6 Roman column (p. 177)

He also discussed the importance of focal points in art and design, and emphasized how visual art can guide the audience's attention through organizational elements. Gombrich

(1979) explained: "The setting of concerns is the key to design and composition, and the artist guides the viewer's eyes through the prominent elements in the composition, so that he can quickly understand and perceive the overall order of the work" (p. 106).

Gombrich (1979) further pointed out that key elements in art are often highlighted by means of contrast, shape and color, so as to provide a visual starting point for the audience: "In an orderly composition, the concerns play the role of focusing, which not only attracts attention, but also helps the audience find an understanding path in a complex visual scene" (p. 108). This shows how the sense of order can enhance the readability and attractiveness of works by setting a clear visual focus in artistic creation.

Utilizing focus points is a fast way to present information. More emphasis can be placed on these concerns in the design. Focus points can help the observer quickly obtain the information to be displayed.

#### 2.3.4 Lateral inhibition

Lateral inhibition is a key regulatory mechanism in the nervous system, manifested as the inhibitory effect of nerve cells in an activated state on peripheral similar cells. This mechanism optimizes the efficiency of information processing by selectively enhancing the dominant signal - when external stimuli act on neural clusters, only the units that receive the strongest input and have the lowest degree of inhibition can form effective discharges. This competitive screening mechanism has a core value in visual perception. Its function runs through all levels of information processing links in the visual pathway, specifically manifested as improving the accuracy of image parsing by enhancing spatial contrast sensitivity. Although this is a biological phenomenon, the final result will be reflected in visual perception.



Figure 2.3.7 Mach band illusion (Aliwiki, 2006)

From the perspective of visual perception, the color one pays attention to will be influenced by the surrounding colors. In the Mach band illusion (Figure 2.3.7), along the boundary of adjacent gray shadows, lateral suppression makes the darker areas appear darker and the brighter areas appear brighter (Geier, 2011). When faint light appears in a dark environment, the receptors located at the center of the stimulus on the retina will be activated and transmit visual information to the brain, while the receptors located on the periphery of the stimulus will send inhibitory signals to enhance the perception of the surrounding dark environment. This process will produce a greater low-light contrast and lead to a Mach band visual effect (Cohen, 2011).

## 2.4 Conclusion

From a series of historical examples, we can see that the application of perception principles is not something that emerged out of thin air or was discovered by accident by people. Instead, people intentionally used perception effects and applied them in real life, from the primary use of perception principles by people in ancient Greece and ancient Rome, followed by greater utilization and research of perception due to the rise of church architecture in the Middle Ages, and then to the Renaissance, people began to use perception in a scientific way. In these periods. Perception affects all served objects that are detached

from daily life, such as high art and architecture. Moreover, perceptual effects served as a tool for presenting a perfect vision.

After the Industrial Revolution, the scientific field of perception grew explosively. Various types of perception theories and studies were proposed one after another. These theories are different from the perception effects previously used for churches and art, so that perceptual influences were presented in a more prominent visual way.

As modernity approached, more and more perceptions were being applied in some ways that are closer to entertainment. These perceptions were no longer used to present a perfect visual effect, but as an interesting one.

And in modern times, when these theories and principles have been used in various ways, furniture, however, has had few opportunities to intersect with the field of perception. As shown in the literature review, perceptual theories and effects can be used in architecture and art so designers can apply those principles to furniture, also a visual object.

Therefore, here is an opportunity to provide designers with a systematic design tool that gives designers the opportunity to utilize a scientific understanding of perception to expand their design inspirations and approaches that can help designers create more visually appealing furniture.

## Chapter 3 Design Approach

### 3.1 Overview

In today's design industry, the continued development of furniture design has never ceased. Designers are constantly exploring various design languages. The support of modern technology can help designers better create what they want. People's thoughts have also evolved from meeting survival needs to emotional needs. Against such a backdrop, it is just the right time to expand the design scope of furniture.

Human design has never lost perception as a form of design thinking. Perception and furniture have gone through the long history of human design together. Both were also changed after the Industrial Revolution. Modern perceptual theories and principles have produced many different explanations and phenomena. These effects influence people's judgments in the form of visual illusions. Although many illusions are regarded as purely interesting visual effects, these phenomena have elements that can be used in furniture.

Combining illusions with furniture design can expand inspiration for designers, creating visually appealing furniture. To do so, designers must effectively combine elements of perceptual illusions with furniture while ensuring its usability and guarantee the illusion's visual impact. This chapter presents a formalized design process that allows designers to do so. The complete design tool is presented in Figure 3.1.

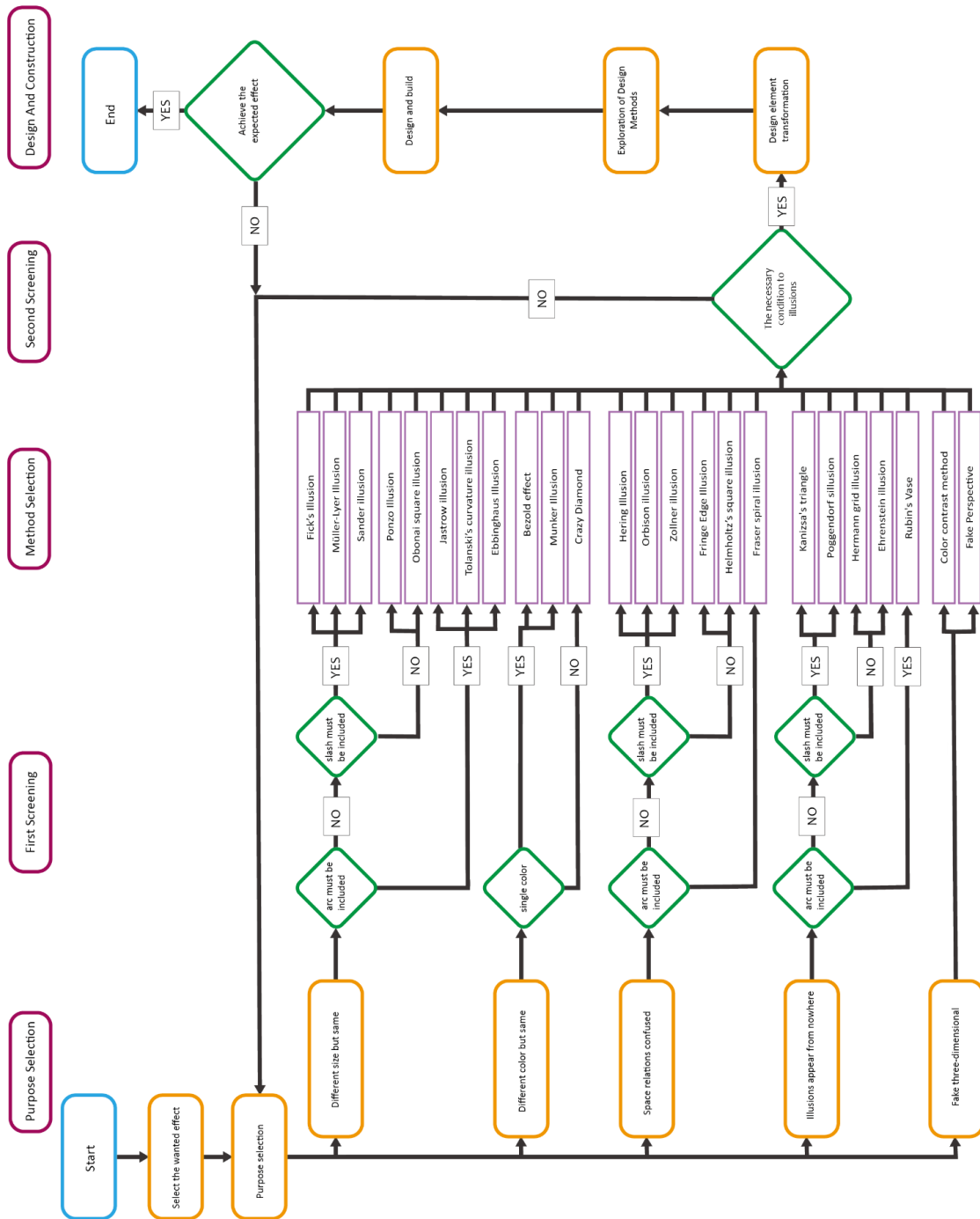


Figure 3.1 Design Tool

This design tool (Figure 3.1) provides clear operational guidance for creators at each design stage by combining structured steps with the corresponding methodology. The specific methods will be elaborated one by one in each section, enabling designers to not only deeply understand the theoretical basis but also master the practical application skills, thereby systematically promoting the design process and achieving the expected results.

The core of the intended furniture design is the chosen illusion. Therefore, choosing the appropriate theoretical basis to choose the best illusions is very important. For designers without full immersion in the field of perception and illusion, guidance is required. The process and tools of the guidelines (Figure 3.1) can help designers quickly select the appropriate illusion and integrate it into furniture design effectively.

This tool helps designers quickly filter out the illusions they want through the checkpoint method. Especially when designers are not familiar with the theories of illusion and perception, individuals can make choices by narrowing down the range through screening. The subsequent analysis of illusions can help designers quickly identify the elements that can be utilized in the design, help them avoid conflicts in the design, and find elements that can be combined with furniture.

This flowchart is a simplification and summary of the entire design tool. The flowchart (Figure 3.2) consists of five parts: Purpose selection, first screening, method selection, second screening, design and construction.



Figure 3.2 Overall Flowchart

3.2 Design Tool

3.2.1 Step 1. Purpose selection.

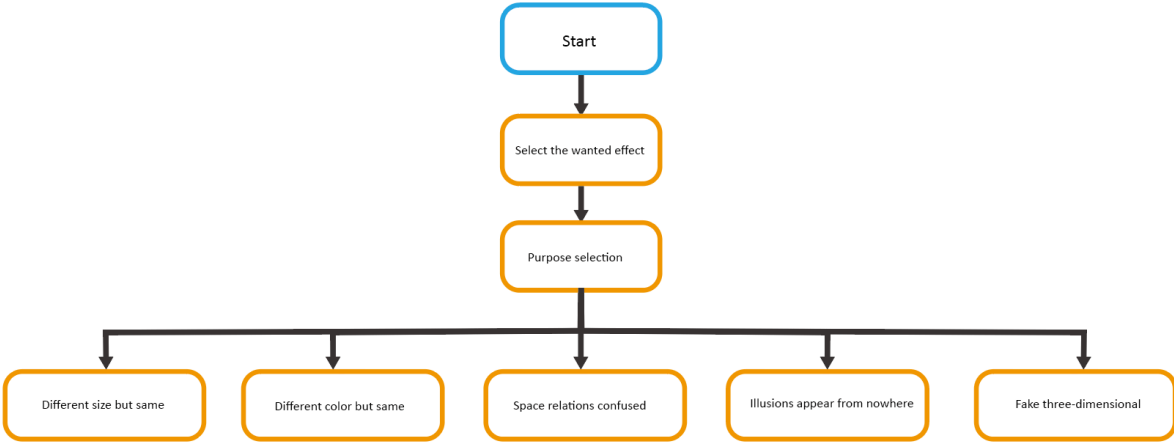


Figure 3.3 Step 1. Options guide.Flow Chart

From this step on, the designer needs to select one of the five options to achieve the illusion effect they want. These effects are as follows: First, the same things, but they present different size effects; second, the same color, but presenting the feeling of different degrees of color; third, the disorder of spatial relations; fourth the effect of existence in non-existent things; fifth, a 3D feel with false effects.

### 3.2.2 Step 2 & 3. First Screening and Method Selection

After the Purpose Selection, designers will come to the First Screening. The purpose of this part is to enable designers to quickly find the illusion methods that match their furniture.

There will also be some differences in the screening methods for different purposes. The following will respectively describe the screening methods that the five different purposes will go through after selection and the illusion Method Selection that will be obtained after these choices.

The part on Method Selection will be explained in detail for each different illusion in the 3.3 Method Selection chapter.

#### 3.2.2.1 Same object different size (Different size but same)

As shown in Figure 3.3, the designers must first select one of the five options to achieve the effect they want.

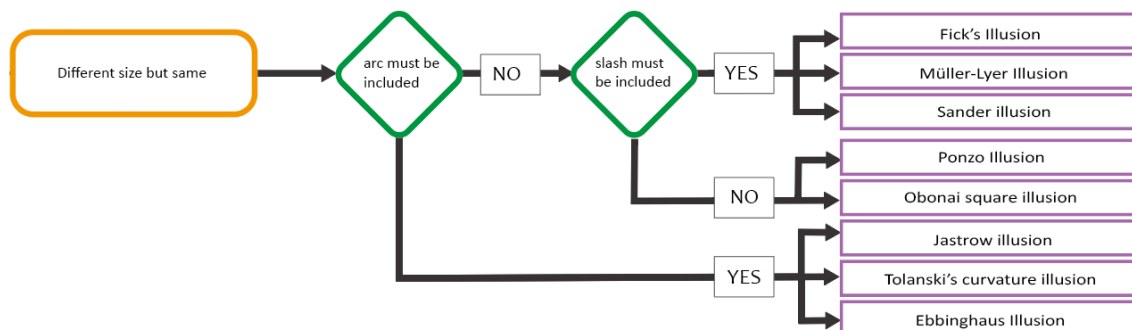


Figure 3.4 Same object different size

After completing the Purpose Selection (Figure 3.4.) There will be two questions in the First Screening. After answering the two questions, different choices will lead designers to different illusion Method Selection. The guide will ask two questions:

Does the furniture you want have to include arcs?

If so, the choice will use one of the following three illusions:

- Jastrow illusion

-Tolanski's curvature illusion

-Ebbinghaus Illusion

If not, go to the second option:

The checkpoint question will ask whether the furniture must include slanting lines.

If so, the choice will be one of the following three illusions:

-Fick's Illusion

-Müller-Lyer Illusion

-Sander illusion

If not, there will be only two illusions left:

-Ponzo Illusion

-Obonai square illusion

### 3.2.2.2 Same object different size (Different color but same)



Figure 3.5 Same color different feeling

The second effect is called Different color but same, meaning the same color, but presenting different feelings. This is different from the process of Figure 3.5. Since this is only through color comparison, the questions in the First Screening will be different. This will guide designers the following:

Does the effect that this furniture is to present only include a relatively single color?

If so, it will be the first two illusions:

-Bezold effect

-Munker Illusion

If not, it would be an illusion:

-Crazy Diamond

### 3.2.2.3 Space relations confusion

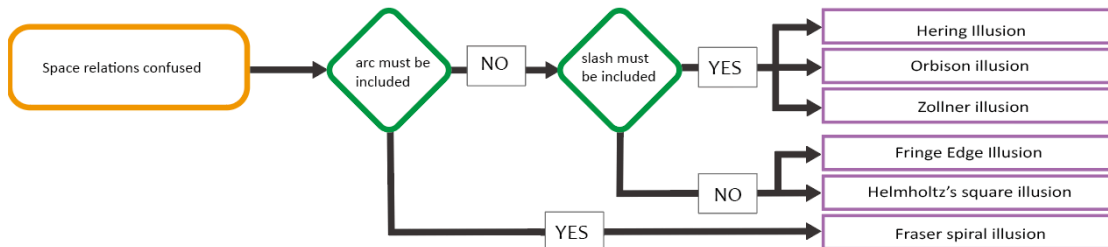


Figure 3.6 Space relations confused

The third effect is the disorder of spatial relations (Figure 3.6). The First Screening asks the same questions as 3.2.1.1:

Must arcs be included in your furniture design?

If so, it will be the illusion at the bottom:

-Fraser spiral illusion

If not, it will lead you to the second question:

Is it necessary to include slanting lines in your furniture design?

If so, it will involve three illusions:

-Hering Illusion

-Orbison illusion

-Zollner illusion

If not, there will be only two illusions left:

-Fringe Edge Illusion

-Helmholtz's square illusion

### 3.2.2.4 Illusions appear from nowhere

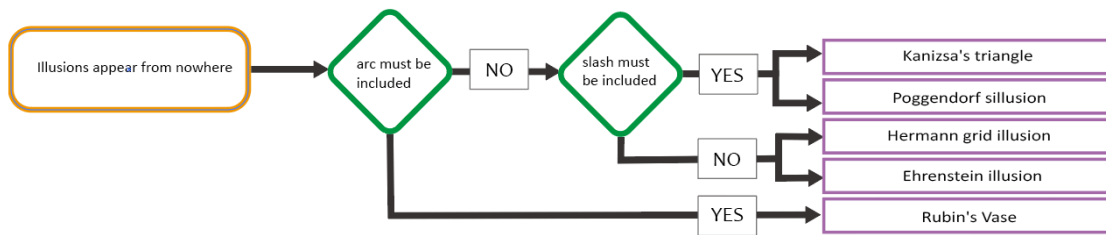


Figure 3.7 Illusions appear from nowhere

The fourth Purpose Selection is called Illusions that appear from nowhere (Figure 3.7), meaning something that does not exist, but is presented. After choosing this purpose, the First Screening will come:

First, should arcs be included in your furniture design?

If so, it will be the lowest illusion:

-Rubin's Vase

If not, you will go to the second question:

Is it necessary to include slanting lines in your furniture design?

If so, it will be the two illusions:

-Kanizsa's triangle

-Poggendorf illusion

If not, it will be the remaining two illusions.

-Ehrenstein illusion

-Hermann grid illusion

### 3.2.2.5 Fake 3d



Figure 3.8 Fake 3D

The last Purpose Selection is fake 3D (Figure 3.8). Because the effect of this purpose is relatively flexible, there are no questions in the First Screening. After Purpose Selection, the designer will directly go to the method of selection:

The first one is to use colors to present a false 3D effect.

The second one is usage. Perspective is used to present a false 3D effect

### 3.2.3 Step 4. Second Screening

After completing the Method Selection, the designer will have the illusion selected. Next comes the Second Screening (Figure 3.9). This section is designed to help designers understand the illusions they have chosen. When the designer understands the content of this illusion, the designer will determine whether this illusion is suitable for the furniture they want to create.

If the content or standard of this illusion is not suitable or conflicts with the furniture designed by the designer (Figure 3.9), designers will be able to return to First Screening and re-select the illusions they desire.

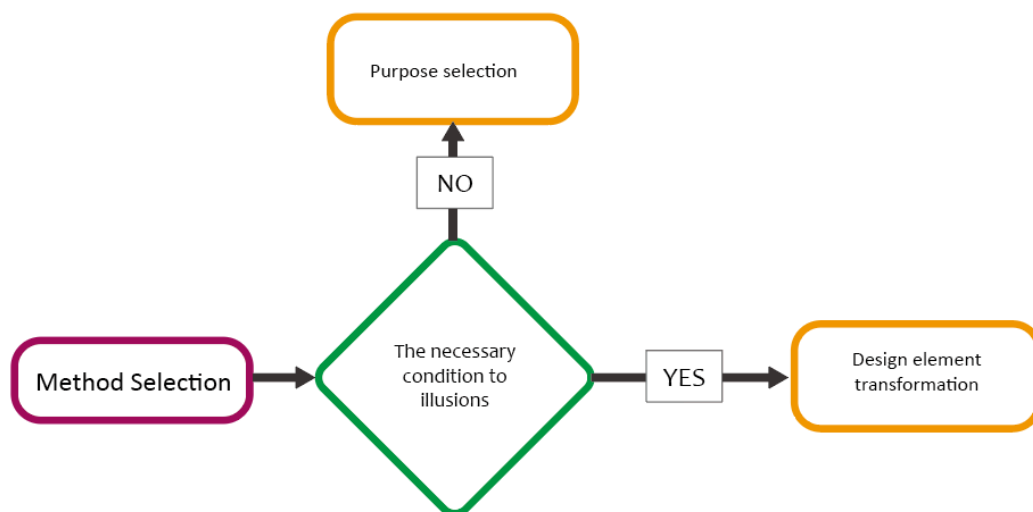


Figure 3.9 Second Screening

**Illusion conditions:** This section will provide some necessary conditions for the illusion to take effect, such as size, proportion, position, color, etc. The role of these conditions is to make this illusion produce its due effect.

This part will not provide a very strict standard, a standard that means completely reproducing the appearance presented by the given illusion because most of the illusions can all produce effects under certain conditions. What is presented here are only some necessary

conditions to ensure a sufficient effect. If these conditions are not met, that effect will decline significantly, or even be ineffective. This section is provided to assist designers in making references and to avoid the decline of the illusion effect due to incorrect use in the design.

After the designer has understood the necessary illusion content, they can understand some of the necessary conditions, such as size, positional relationship, size, color, etc.

If these illusion conditions are regarded as the necessary conditions for the illusion effect and The designer believes that these conditions cannot enable the furniture to be manufactured to achieve a more flexible design, then The designer can go back (Figure 3.9) to the Method Selection and choose another illusion.

If the designer considers these necessary conditions of their chosen illusion acceptable (Figure 3.9), then can move to the final part: Design and Construction.

### 3.2.3 Step 5. Design and Construction.

After the designer chooses a suitable illusion method and is ready to move forward, they arrive at the Design and Construction section (Figure 3.10).

This section will explain how the illusions chosen by the designer will be applied to the furniture. The specific plan will be explained in Section 3.3 Methods Options.

This step will have two important parts: design and construction.

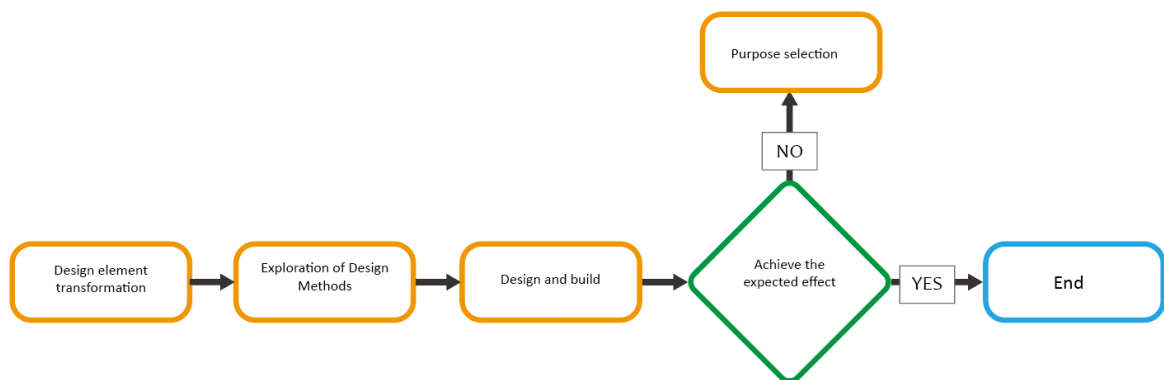


Figure 3.10 Design and Construction

#### 3.2.3.1 Design

The Design section will consist of the important part, Design element transformation. This section explains how the illusion selected by the designer can be utilized and whether these available elements can be transformed into design elements for furniture.

The design is carried out by combining the elements of illusion with those of furniture to help designers expand their design ideas. This section will present some furniture schemes that use the selected illusion. The given solution is not necessary. This plan is merely a design reference to help designers understand on which furniture this illusion can be applied to help designers gain more design inspiration.

### 3.2.3.2 Construction

When the designer creates the design plan, they will move on to the construction part. This chapter will not interfere with the designer's construction methods. Just as a checkpoint (Figure 3.10) at the end of this chapter: Has the design achieved the expected effect, meaning: Does this furniture achieve the desired illusion effect after using the selected illusion?

If the designer is not satisfied with the illusion effect created, they can go back to the illusion selection and choose another illusion, or choose another one in the already selected category.

### 3.3 Methods Options

This section will list a variety of illusions from Step 2 and Step 3. This list will help designers increase their familiarity with illusions, especially the ways and degrees of their influence. Understanding these options will allow designers to filter through the illusions they want to use.

Based on the following content, design recommendations will be given for each illusion. Designers can develop the furniture design they desire based on the illusions screened in steps 2 and 3, combined with available elements and design recommendations.

#### 3.3.1 Same object different size

This kind of illusion mainly involves confusion about the size of objects. Through changing references in the environment, the illusions change the observer's subjective judgment of the size of the object. In other words, the same object shows different effects through the illusion. Designers can add a sense of difference while preserving the main object.

##### 3.3.1.1 Jastrow illusion

The Jastrow illusion refers to two curves of equal length, with the lower one appearing longer than the upper one. Similarly, two identical fan-shaped rings contain the optical illusion that the lower fan-shaped ring appears larger than the upper one. When two identical arc-shaped or ring-shaped objects (such as crescent-shaped or C-shaped in Figure 3.11) are placed side by side in a specific way, one of them will be perceived as significantly larger than the other.



Figure 3.11 Jastrow illusion

**Illusion condition**

Although the original illusion presented a fan shape, subsequent research indicated that similar effects were also observed in various geometric shapes, including trapezoids, parallelograms and rhombuses (Gregson, 1995). Of course, there is also the best way to present the entire illusion. The inner radius should be 60% of the outer radius. The opening angle is 80 degrees. The cutting angle is at the center of the ring. The illusion effect is strongest when the sectors are placed horizontally directly above each other. Overlapping the sectors or moving them too far will destroy the illusion. (Imai,1960).



Figure 3.12 Different Jastrow Illusions

### **Design element transformation**

If the designer selects Jastrow Illusions and chooses not to use the best modeling requirements in the illusion content. Designer can understand it as shown in Figure Figure 3.12: Two identical shapes with a certain degree of curvature that maintain a certain distance within a certain range. This distance and curvature can be adopted more flexibly by designers. In furniture components, objects of the same shape are designed in an arranged manner. Curved shapes can be partitions or accommodating spaces.

According to the description in the design elements, we can infer the following several design schemes: The same shape with curvature serves as the space for accommodating items, arranged in an up-down arrangement like Figure 3.13. This way, furniture for storage can be obtained, such as cabinets, bookshelves, etc. Arc-shaped graphics can also be used as backplanes, which can counteract the influence caused by perspective in the 3D state, on the surface of the back panel.

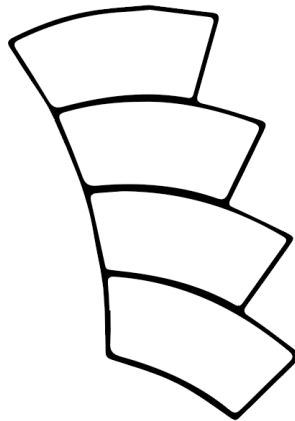


Figure 3.13 Arranged Jastrow Illusions

### 3.3.1.2 Muller-Lyer Illusion

The Muller-Lyer Illusion is a classic geometric visual illusion phenomenon, which was proposed by the German psychologist Franz Muller-Lyer in 1889. Its core manifestation is composed of a group of arrow-shaped graphics (Figure 3.14). Equal-length straight line segments form the "arrow shaft" of the arrow, while shorter line segments (referred to as the tail) extend from the end of the arrow shaft. The tail can point inward to form an arrow "head", or outward to form an arrow "tail". This leads the observer to believe that the line segment of the arrow shaft with two tails is considered longer than that of the arrow shaft with two heads (Gregory, 1997).

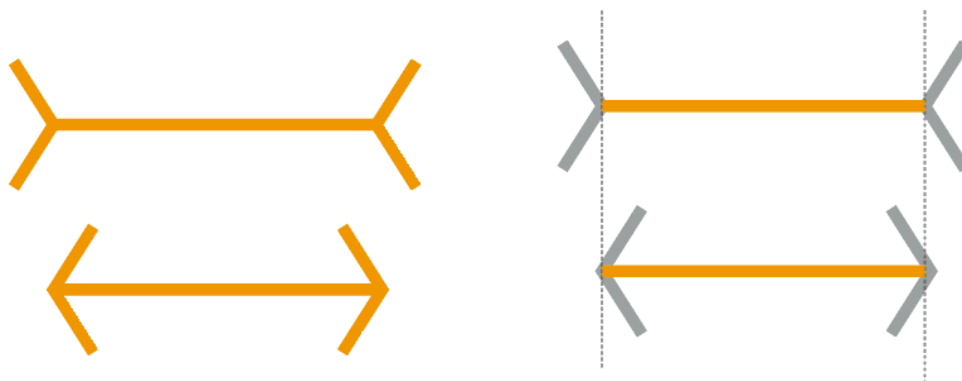


Figure 3.14 Muller-Lyer Illusion

#### **Illusion condition**

The effect of illusion is not determined by the shape or direction of the arrow. Convex angles and concave angles have little influence on the Muller-Lyell effect (Purves, 2005). The perceived length variation is caused by the local position change of the stimulus termination point (for example, the vertices of the wing in the Muller-Lyell mode as shown in Figure 3.15), rather than due to the uniform expansion or contraction of the graphic axis (Bulatov, 2011).

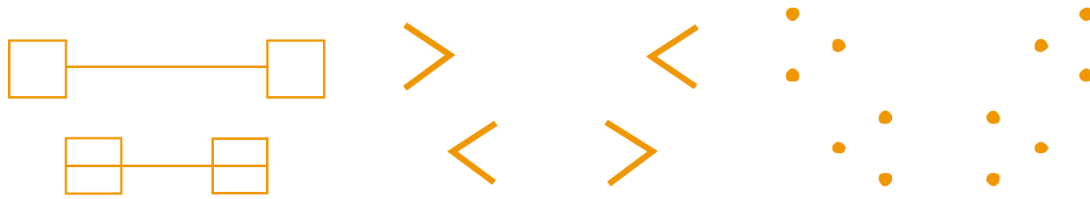


Figure 3.15 Different Muller-Lyer Illusion

### Design element transformation

Through the analysis of the content, we can determine that the most influential factor lies in the vertex position of the outer shape. The designer only needs to ensure that there are shapes with different vertex positions in the adopted shapes as shown in Figure 3.15. There is an illusion effect when the vertex position is guaranteed. According to the Law of Closure in section 2.3.1, the middle line segment can be ignored to some extent because people will automatically connect the endpoints as shown in the image on the right of Figure 3.15.

The designer can take the parts of furniture that can be arranged in a certain way as the entry point, which are like linear segments, for example, partitioning. Furniture with partitions includes cabinets, shelves, railings, etc. Since the influencing factors do not include location, designers can also obtain different designs by changing the position.

This illusion involves straight lines. The designer uses straight lines as panels and applies them to all furniture with partitions and wooden boards. The part of the "arrow" serves as a partition between each floor. The blank spaces between the line segments are used as accommodation spaces, for example, the partition between each layer of the cabinet.

### 3.3.1.3 Ponzo Illusion

Proposed by the Italian psychologist Mario Ponzo in 1911, this illusion is manifested as when two horizontal line segments of equal length are against the background of prospective lines (such as railway tracks, corridors), the line segment located above will be perceived as longer (Figure 3.16). This illusion stems from the brain's incorrect inference of the distance of an object through perspective cues (such as linear perspective), and thereby misjudging its size (Bertamini, 2023; Ponzo, 1911).

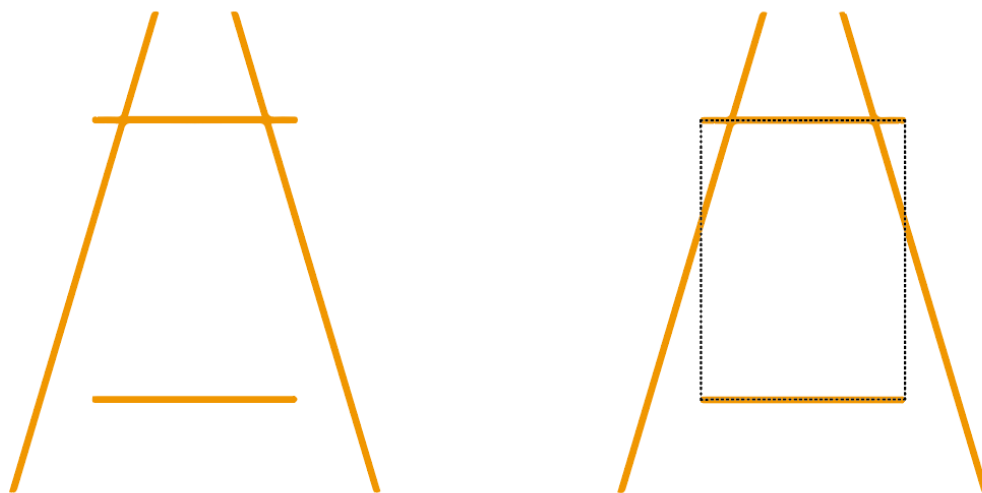


Figure 3.16 Ponzo Illusion

#### **Illusion condition**

The effect of this illusion requires a converging background line in perspective (for example, two converging straight lines) to provide depth implications. The superposition of multiple deep clues can enhance the intensity of the illusion. Linear perspective cues all increase the degree to which distant targets are magnified. When both the linear perspective and texture cues are provided simultaneously, the illusion effect is stronger than when only a single cue is provided, and the effects of the two have a superimposed effect. On the contrary,

the amplitude of the illusion will be significantly weakened. When the convergence angle (the angle between the perspective lines) is moderate, the illusion is the greatest. If the perspective lines are almost parallel or the included angle is too large, the illusion effect will be reduced. Even when the perspective lines are extremely inclined, the direction of the illusion may reverse (Gandhi, 2015; Yildiz, 2019).

### **Design element transformation**

The perspective lines required for the background are the key to the illusion effect. This kind of perspective line can be used as a component of the strip in furniture, for example, cabinets, shelves, etc. There is no influence of position. Designers can place the perspective lines at any angle. If placed horizontally, the designers should increase the perspective lines. Parallel lines are added to the bottom for supplementation, with the perspective line as the background. Parallel lines can be made into shelves. As shown in Figure 3.17, the objects placed on each layer naturally become the objects of comparison. If the orange square in Figure 3.17 is changed to the accommodating space, A cabinet can be obtained.

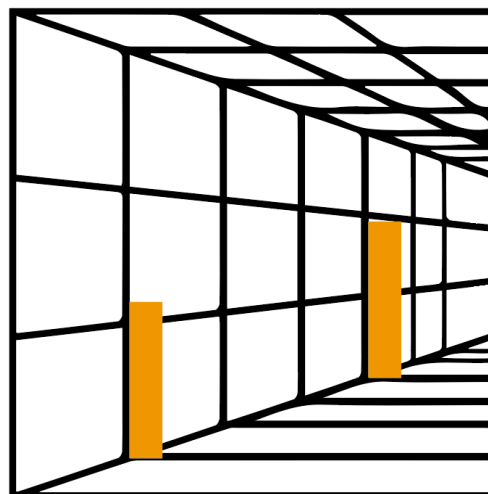


Figure 3.17 Ponzo Illusion example

### 3.3.1.4 Tolanski's curvature illusion

Tolanski's curvature illusion is an optical illusion phenomenon caused by the arrangement of lines or patterns, and its core manifestation is that parallel straight lines are perceived as curved under a specific background or contrast. As shown in Figure 3.18, these three arcs seem to have very different degrees of curvature, but in fact they are exactly the same, with the only difference being the lower two are shorter than the upper one.

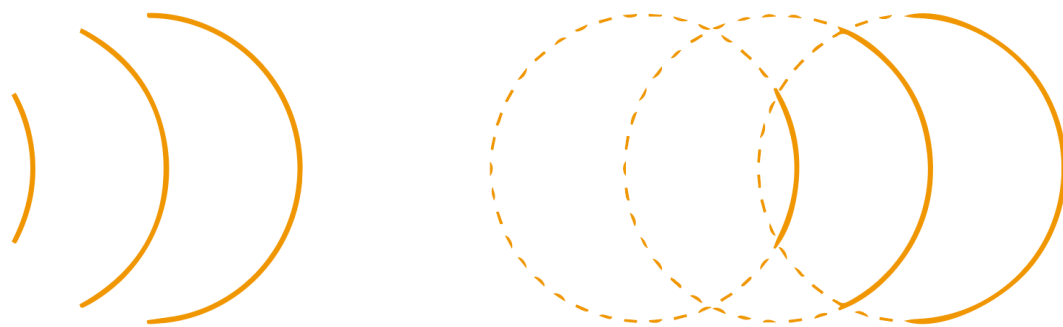


Figure 3.18 Tolanski's curvature illusion

#### **Illusion condition**

The Tolanski curvature illusion refers to the visual illusion that arc segments from the same circle (i.e., with the same radius of curvature) show differences in curvature due to different visible arc lengths. The longer arc segments in the visible part appear to bend more obviously, while the shorter arc segments in the visible part appear to be more gentle (Ninio, 2014). Studies show that the perceived curvature monotonically increases with the increase of arc length. The illusion effect reaches its peak when the arc length corresponds to a central angle of approximately  $60^\circ$ . If the arc length is increased further, the perceived curvature no longer increases significantly. An angle of  $22.5^\circ$  is the minimum value. (Schmidtman, 2016).

## **Design element transformation**

The illusion utilizes curves from the same circle. The entire illusion is composed of the same arc-shaped line segments. Line segments can be transformed into strip components in furniture or used as part of a shape. Many pieces of furniture have curved designs, such as door frames, cabinets, stools, etc. The order of arrangement can also serve as an entry point to design. There are many pieces of furniture that need to be placed up and down, such as cabinets, shelves, etc. In addition to the structure, patterns in the same sequence can also be used as design references and integrated into the design, for example, on the panel of the table.

Under the condition of this illusion, the direction is not specified. The designed furniture can take this illusion into account from any angle. As partitions between each floor, they are distributed up and down. Since they come from the same arc, this feature can be utilized to design the three lines as foldable components, such as push-pull or free-fall opening and closing assemblies. A simple solution can also lay the illusion flat on the board as a pattern.

3.3.1.5 Sander illusion

The Sander illusion or Sander's parallelogram was proposed by the German psychologist Friedrich Sander in 1926. The illusion presents the effect that two equal-length line segments are disturbed by the surrounding background shape of a parallelogram (Colman, 2006), as shown in Figure 3.19. These two line segments (the orange line segment) are considered to have different lengths.

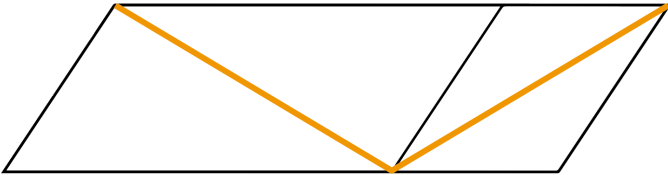


Figure 3.19 Sander illusion

As shown in Figure 3.20, the two orange line segments are surrounded by a circle. The orange segments are placed at the center of the circle, which indicates that the orange lines are of the same length.

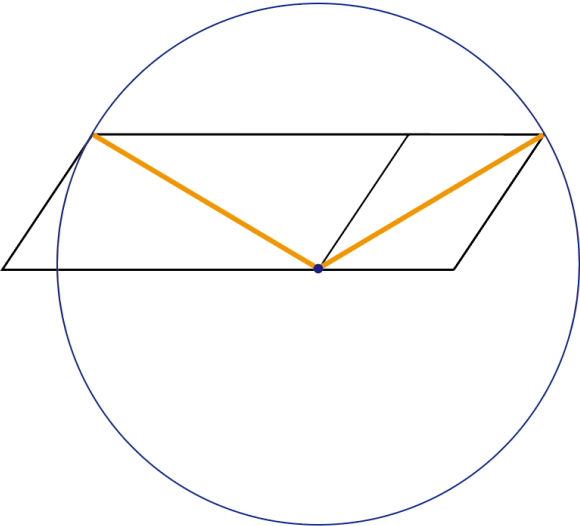


Figure 3.20 Sander illusion with circle

### **Illusion condition**

When the areas of two parts of a parallelogram are nearly equal, the two diagonals of the same length almost no longer create the illusion of length difference. When one side of the area is significantly larger than the other side, the diagonal within the large area will be overestimated for a longer time. Increasing the size difference of the background frame will enhance the length illusion, while reducing the difference will weaken the illusion or the illusion will disappear when they are exactly equal (Cooper, 1972)

### **Design element transformation**

The background of the illusion is a parallelogram. The line segments of a parallelogram can serve as the boundaries or edges of an object. Designers can achieve this by retaining the features of a parallelogram and then thickening the exterior of the line segment. Because there are two identical line segments in the middle of a parallelogram, designers can utilize the same features of line segments to obtain a circle with the same radius as the length of the line segment through rotation. A rotatable structure can be designed to enable the two line segments to overlap, or the designer can use the parallelogram as the backplane, for example, door frames or the doors of lockers. The two identical line segments in the middle can be designed as door handles.

### 3.3.1.6 Ebbinghaus Illusion

This illusion is named after its discoverer, the German psychologist Hermann Ebbinghaus (1850-1909). The most famous manifestation of this illusion is when two circles of the same size are placed side by side, with one circle surrounded by a larger one and the other by a smaller one, shown in Figure 3.21. Because the circles are side by side, the central circle surrounded by the large circle appears smaller than the central circle surrounded by the small circle (Roberts, 2005).

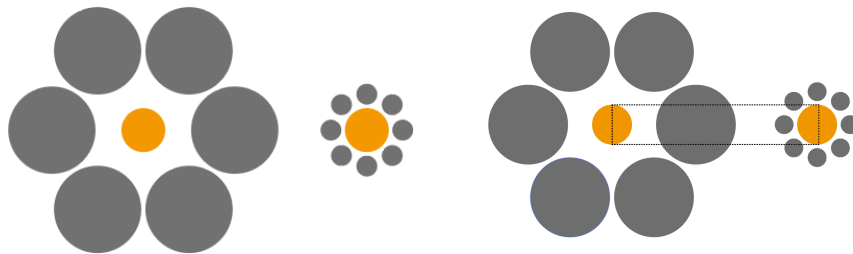


Figure 3.21 Ebbinghaus Illusion

#### Illusion condition

The Ebbinghaus illusion is not limited to the original circular pattern. Rashal et al. (2020) used squares composed of angles as targets and inducers to prove that even if the shapes and structures are different, the relative size background can still cause significant illusions. The classic Delboeuf illusion (Figure 3.22) is also regarded as a special case of the Ebbinghaus illusion. When the surrounding induced ring becomes a continuous ring band, the resulting central circle size illusion is similar to the effect of multiple small circles surrounding (Rashal, 2005).

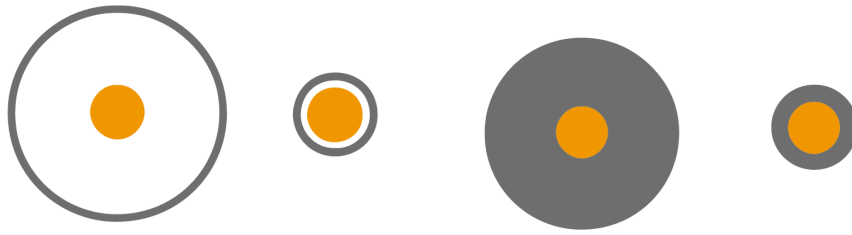


Figure 3.22 Delboeuf illusion

### **Design element transformation**

Under the premise that encirclement is the main influence, the components with enclosure features in the furniture can be used as the starting point. If the circle is not considered, the square shape can be designed as a cabinet. This gap serves as a partition wall and the square represents the storage space with different small storage spaces surrounding. The same pattern can be overlapped and utilized as a feature, for example, in a shelf. The enclosed pattern can serve as the connection between different layers of the shelf. They can be connected because of the same size. The surrounding pattern can be made into a feature of the storage space.

### 3.3.1.7 Fick's Illusion

Fick's Illusion was first proposed by the German physiological psychologist Adolf Fick in 1851. Later, after in-depth research by Theodore Kunnapas, it was called the horizontal-vertical illusion (Figure 3.23). The illusion is that when the vertical line segment is juxtaposed with the horizontal line segment of the same length, the vertical line segment is perceived as longer (Kunnapas, 1955).



Figure 3.23 The Obonai square illusion

#### **Illusion condition**

The content is the same as the description of this illusion: Two vertically related line segments of the same length.

#### **Design element transformation**

Through the phenomenon that the vertical line is longer than the horizontal line, designers can add more vertical lines in the square space, but the side lengths of the squares are the same as those of the vertical lines, which makes the whole appear taller. This pattern can also be applied to a board, for example, a door panel or the surface of the cabinet, etc. to increase the sense of height.

### 3.3.2 Same color different feelings

Color illusion is the use of color related principles to create illusion. Because furniture can be any color or colors, the illusion of color can also be applied to furniture. This illusion allows furniture to use less color while making the furniture more intuitive and interesting.

#### 3.3.2.1 Bezold effect

The Bezold was named after its discoverer, Wilhelm von Bezold (1837-1907). A color may appear different because of its relationship with adjacent colors (Albers, 1963). As shown in Figure 3.24, under different contrasts of the same kind of red, the illusion of being bright or dark is presented. The red and white on the left look darker, but on the right, when red is surrounded by black, it looks brighter. But in fact, the red on both sides is exactly the same.

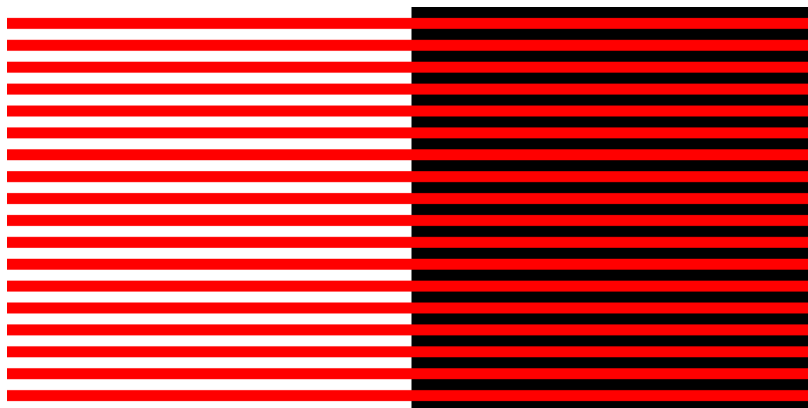


Figure 3.24 Bezold effect Red with Black and White.

#### **Illusion condition**

According to the Gestalt rule of Lateral Inhibition in section 2.3.4, the area surrounded by the bright area appears darker, while the area surrounded by the darker area appears brighter. This illusion principle has also branched out into many other famous versions.



Figure 3.25 Grayscale Illusion

As shown in Figure 3.25, the gray levels of the two vertical gray bars on the left and right are the same, but it seems that the color on the left is darker than that on the right. This is also caused by the factor of Lateral Inhibition.

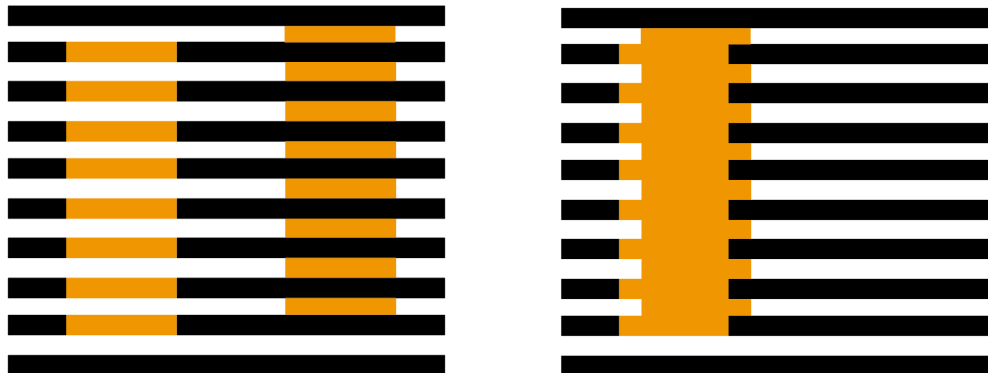


Figure 3.26 Munker Illusion

The Munker Illusion adopts the same principle, Lateral Inhibition. The orange color in Figure 3.26 is the same. But under the effect of illusion, it presents as different colors.

### **Design element transformation**

As an illusion of color, there are no restrictions on shape and size. It should be noted that this illusion requires the colors to come into contact with each other and high-contrast colors

are needed to achieve a better visual effect. But in reality, there are many factors that affect colors, such as lights and shadows. All of these will cause changes in the effect, so attention should be paid when designing.

This color type can be used on the surfaces of various boards such as doors and cabinets. By taking advantage of the visual effect of the fence, two identical colors can be overlapped to create an opportunity to display the same color, for example, sliding doors and windows. In furniture design, large areas of high-density stripes can also be used as board surfaces.

### 3.3.2.2 Shadowed diamond illusion

The shadowed diamond illusion is also known as "dynamic diamond illusion" (Figure 3.27). This illusion was proposed and refined by the Japanese mathematician and optical illusion artist Kokichi Sugihara in 2010. The appearance it presents is like rhombic bricks and stones of different colors. But in fact, each rhombus has the same color.



Figure 3.27 Dynamic Diamond

This is an illusion that has developed from the Cornsweet illusion, which is a kind of visual illusion phenomenon described in detail by Tom Cornsweet in the late 1960s (Cornsweet, 1970).



Figure 3.28 Cornsweet illusion

As shown in Figure 3.28, the illusion is composed of a gray rectangle. The left half of it gradually becomes lighter as it approaches the vertical centerline, while the right half gradually becomes darker as it approaches the same centerline. The entire left half of the rectangle appears brighter than the right half, but by blackening the middle part, it can be demonstrated that the actual brightness of the two outside areas is exactly the same (Lotto, 2021).

### **Illusion condition**

The diamond illusion and the Cornsweet illusion principle comes from the rule of Lateral Inhibition (section 2.3.4). Gradient colors were used in Figure 3.29..

### **Design element transformation**

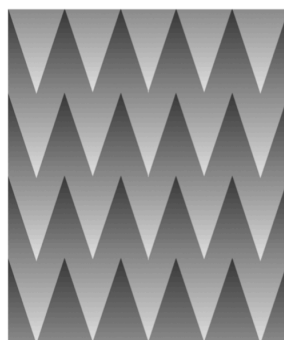


Figure 3.29 Cumulative Cornsweet effect by Isao Watanabe & Patrick Cavanagh

Drawing from the variant shown in Figure 3.29, equidistant permutations and combinations can enhance the effect. The superimposition of each layer can be used as the interval between each layer on a furniture shelf. That layering can also be used on flat plates in a simple way, but designers should pay attention to the influence of real light and shadow on the effect.

### 3.3.3 Space relations confused

The following illusions distort the viewer's sense of space in the image in question in several ways. Such illusions used on furniture can not only reduce the processing of curves, but also produce distortion through the illusion effect.

#### 3.3.3.1 Hering Illusion

Hering Illusion was proposed by the German physiologist Ewald Hering in 1861. When two parallel lines appear in front of a radial background (Figure 3.30), these lines seem to curve outward.(Hering,1861)

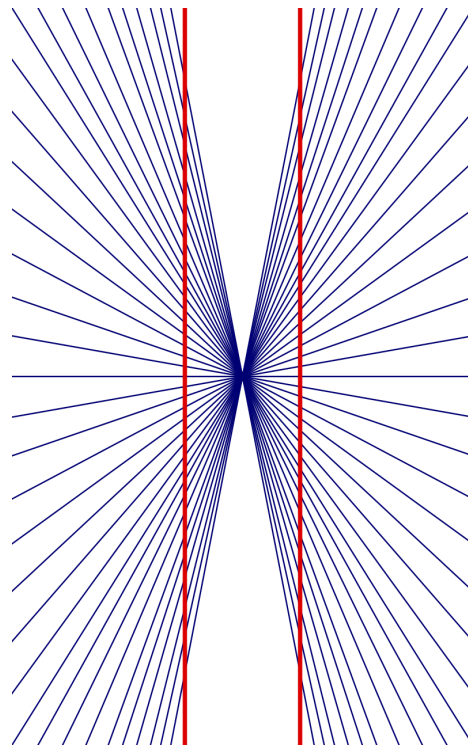


Figure 3.30 Hering Illusion

The Orbison illusion (Figure 3.31) is one of its variants, which is a shape illusion proposed by the American psychologist Orbison. Its effect is composed of a two-dimensional figure (superimposed on a background made up of radiation or concentric circles), shown in Figure

3.31. The result is a visual illusion, with both the figure and the rectangle containing it appearing distorted (Roeckelein, 2006).

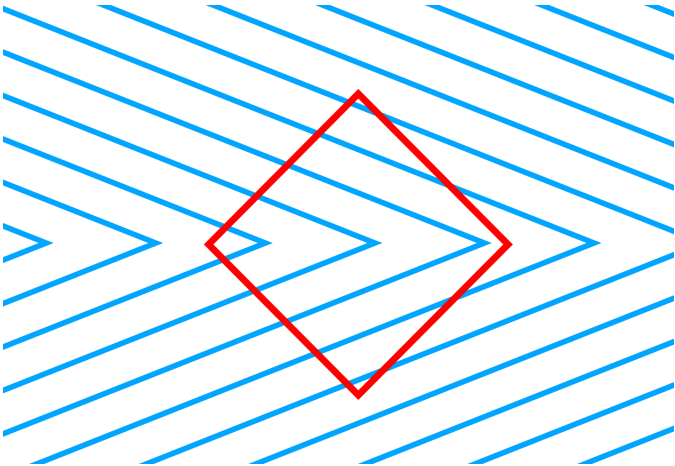


Figure 3.31 Orbison illusion

The Wundt illusion (Figure 3.32) produces a similar but opposite effect from the Hering illusion (Nicholas, 2007).

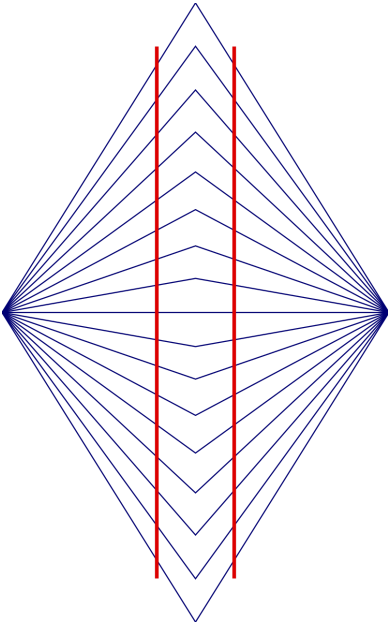


Figure 3.32 Wundt illusion

These illusions' principle is to simulate the depth cues in natural scenes (such as railway tracks extending into the distance) through radial lines, triggering the brain's misjudgment of spatial perspective and causing parallel straight lines to seem curved (Gregory, 1968).

### **Illusion condition**

The content and effect of illusions are similar. The radial line segments distorted the straight line.

### **Design element transformation**

The straight line placed on the radial line segment can be adapted because many pieces of furniture have wire segments, such as fences, screens, railings, etc. All of these can be made into line segments to create a similar illusion effect. The main objects can be generated on these line segments. The Orbison illusion allows the existence of geometric shapes, and these line segments are not radial either. Square and other geometric shapes can be used as storage space for cabinets. Line segments serving as auxiliary objects can form a background like parentheses. Symmetrical designs can be used as screens or double doors. Line segments can be decorative elements on the board.

### 3.3.3.2 Fringe Edge Illusion

The Fringe Edge Illusion refers to the phenomenon of distortion of a shape, movement or color perception caused by specific stripes or gradient designs at the edge or boundary of an object. Its classical form is closely related to Mach Bands and was first described by the Austrian physicist Ernst Mach in 1865. Adding directional stripes (such as diagonal or radial) to static edges can trigger motion illusions (such as rotation or fluctuation) (Kitaoka, 2003).

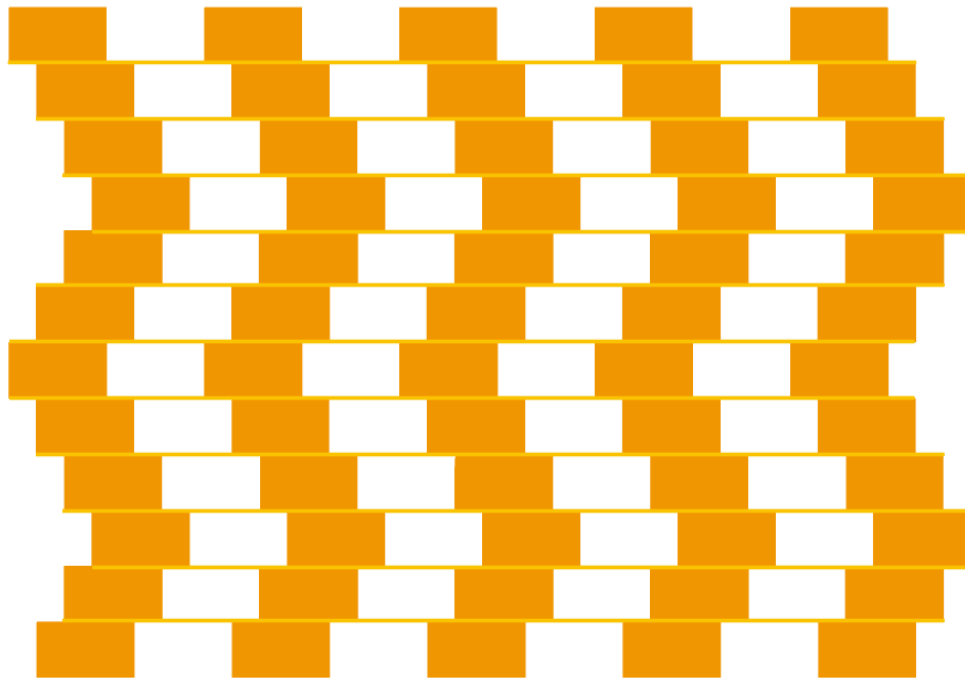


Figure 3.33 Fringe Edge Illusion

#### **Illusion condition**

The mutual inhibition of adjacent neurons in the retina intensifies the edge contrast of brightness or color, resulting in false bright and dark bands or shadows at the junction of light and dark. The response of retinal ganglion cells to high-contrast boundaries takes precedence

over uniform regions, triggering overcompensation of the margins in the brain (Livingstone & Hubel, 1988).

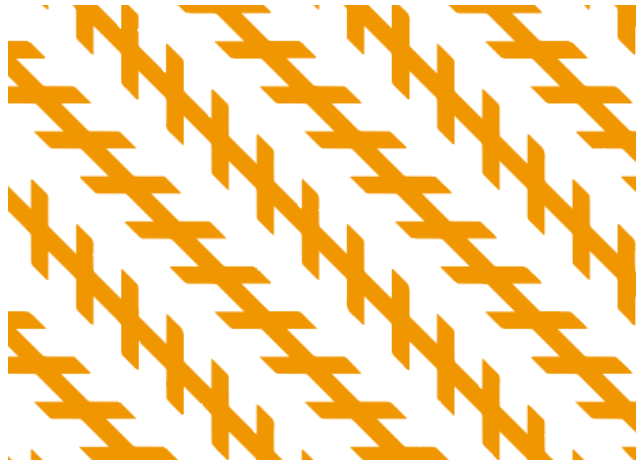


Figure 3.34 Zöllner illusion

Another well-known variant is the Zollner illusion (Figure 3.34). It was discovered by the German astrophysicist Zorla in 1860. Originally, the illusion was composed of a group of parallel line segments. However, after adding some additional line segments, they no longer appear parallel (Kitaoka, 2000). Such an illusion occurs because the direction-sensitive neurons in the visual cortex (V1 area) have a competitive response to the angle difference between the cross diagonal and the main line, resulting in the parallel lines being misjudged as divergent or convergent (Hubel & Wiesel, 1962).

### **Design element transformation**

In this illusion, there are both bars and rectangles. The arrangement and combination of rectangles can be transformed into partitions in furniture. A large piece of furniture can be obtained through arrangement and combination. Line segments can be converted into baffles. Shelves can be obtained through arrangement and combination. A simple form can be placed as a pattern on a flat surface. If the transformation is mainly composed of line segments, it

can be used as a shelf layer. Horizontal line segments can serve as frames and diagonal lines as backgrounds. The gaps between line segments can be converted into storage space. If the transformation is mainly rectangular, it can be used as a cabinet. Parallel line segments can serve as partitions in the middle of each floor. It is worth noting that the Fringe Edge Illusion and other illusions based on the same principle all require high-contrast colors to be achieved. In actual design, attention should be paid to the influence of light and shadow caused by reality.

### 3.3.3.3 Fraser spiral illusion

The Fraser spiral illusion was depicted by the British psychologist Fraser in 1908. The pattern of black and white line segments composed of concentric circles (Figure 3.35) is wrongly perceived as a spiral (Fraser, 1908).

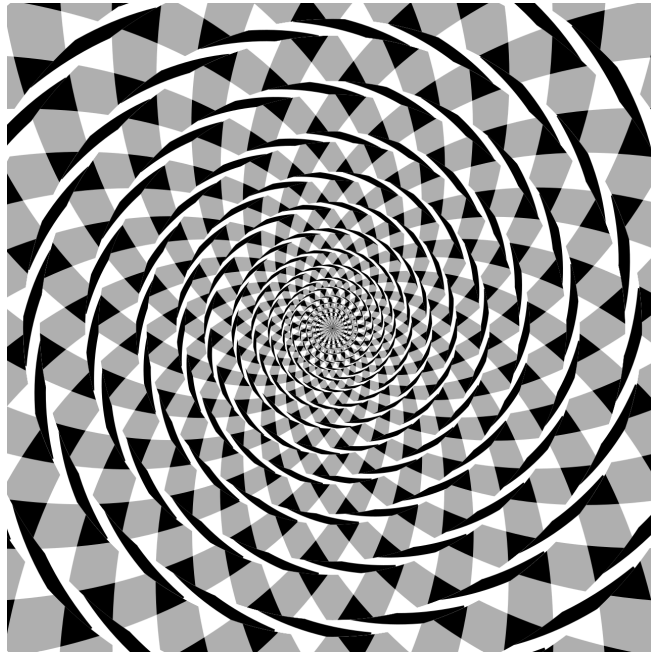


Figure 3.35 Fraser spiral illusion

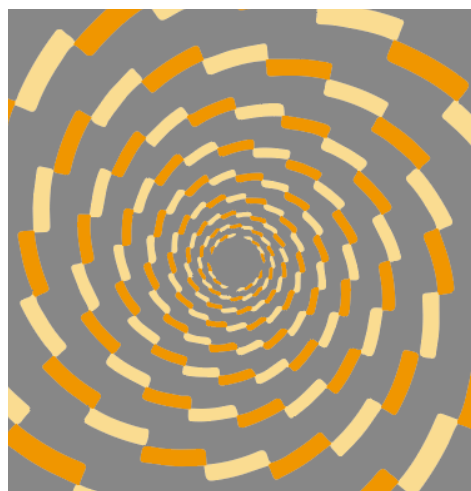


Figure 3.36 Simplified Fraser spiral illusion

### **Illusion condition**

The Fraser spiral illusion is composed by combining regular line patterns (circles) with unaligned parts (lines of different colors). The Zollner illusion in Section 3.3.3.2 is based on the same principle that numerous tilted elements can cause the eyes to perceive illusory distortion and deviation (Cucker, 2013).

### **Design element transformation**

The most likely way for complex illusions to occur is when they are used as patterns on boards. However, after simplification, as shown in Figure 3.36, the effect did not disappear even when the background was eliminated. Designers can transform the illusion in this way to apply to furniture such as a circular cabinet.

### 3.3.3.4 Helmholtz's square illusion

Proposed by the German physiologist and physicist Hermann von Helmholtz in the 19th century, the Helmholtz square illusion (Figure 3.37) is manifested as two squares of equal area being perceived as different in size or shape due to the influence of the direction of the background lines. Since background lines (such as radial or parallel lines) can interfere with the brain's geometric analysis of the target shape, the boundary contrast is strengthened through Lateral Inhibition, resulting in shape misjudgment (Helmholtz, 2005). The perspective relationship suggested by background lines (such as radial lines simulating spatial extension) triggers the brain's "dimensionality - distance constancy" compensation, allowing misjudgment of the square proportion (Gregory, 1968).

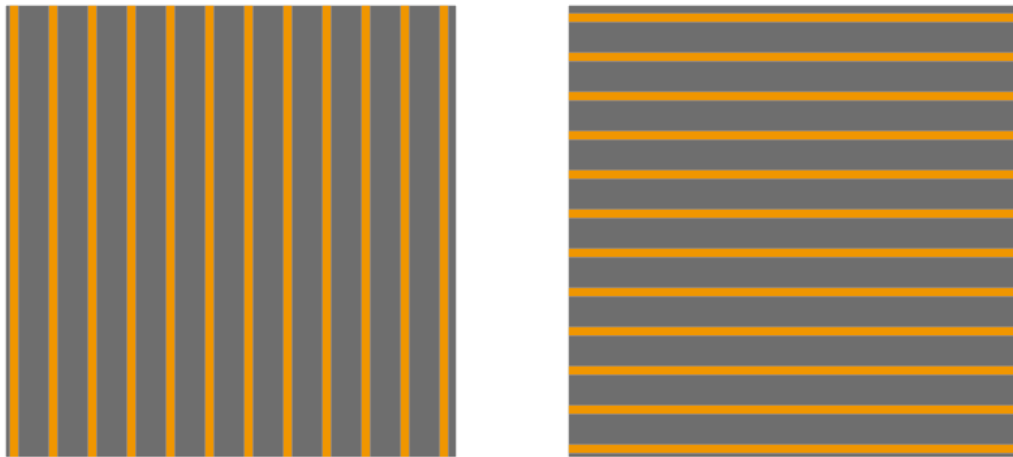


Figure 3.37 Helmholtz's square illusion

#### **Illusion condition**

This illusion is composed of vertical and horizontal lines in the same square. The principle is similar to Fick's Illusion in 3.3.1.7.

#### **Design element transformation**

Line segments can be transformed into strip structures in furniture, or the designer can adopt vertical strip railings. This transformation can make the doors, frames or panels of this

structure look longer. On the contrary, the door or frame can appear wider with horizontal lines

### 3.3.4 Illusions appear from nowhere

This illusion will make something appear by some means that does not exist. Such non-existent things are not visually non-existent. It is the illusion that something objectively exists in something that is not created subjectively. The advantage of this is that the designer can use other methods to show the desired effect. In furniture there is an opportunity to create unexpected shapes with less material.

#### 3.3.4.1 Rubin's Vase

Designed by Danish psychologist Edgar Rubin in 1915, this illusion is generally referred to as "Rubin's Vase (Figure 3.38)" (Khalil, 2021)



Figure 3.38 Rubin's Vase

#### **Illusion condition**

Rubin's Vase relies on the Gestalt principle of the Figure-ground. The pattern of the vase itself and the human face can be regarded as either the Figure or the Ground respectively. Depending on the different objects of observation, the relationships among the vase itself and the human face can be transformed into each other.



Figure 3.39 Kanizsa's triangle

### Kanizsa's triangle

The Kanizsa's triangle illusion (Figure 3.39) partially aligns a circle with a cut corner with a line segment, creating a triangular shape at the edge and triggering the perception of an illusion contour. Although Kanizsa's triangle does not have a definite triangular component, it can evoke the perception of a shape, which is defined by a clear illusory outline (Kanizsa, 1955).

The reason for this illusion phenomenon is Law of Closure (in section 2.3.1). The human brain automatically completes the missing triangular part.

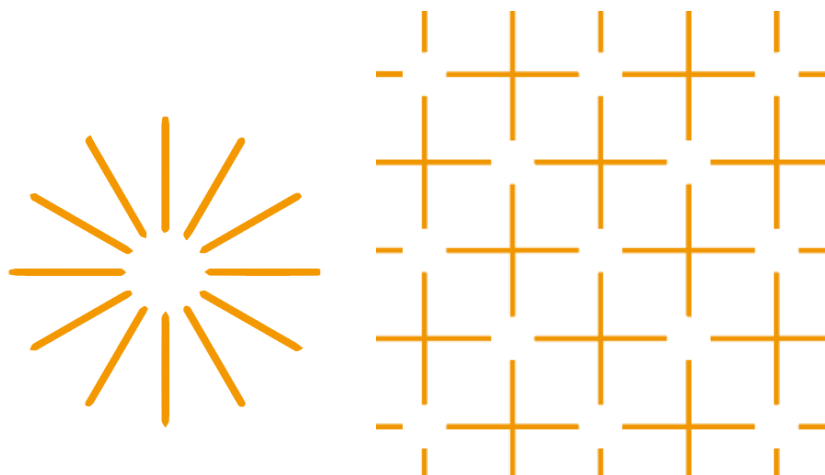


Figure 3.40 Ehrenstein illusion

The same principle is also used by the Ehrenstein illusion (Figure 3.40). The Ehrenstein illusion was designed by the German psychologist Walter Ehrenstein in 1941. In the picture, white circles seem to be drawn at the intersection of the broken horizontal and vertical lines, but in fact, they do not exist. Once a thin ring is added, it will instead destroy this illusion (Ehrenstein, 1941).

### **Design element transformation**

This illusion has flexible conditions and restrictions. Designers can use any pattern that humans can recognize for their designs. Designers can add it to items that resemble a vase. It can also be removed from the image like a triangle. In other words, the designers should make use of the principle behind this illusion. Any specific object can be substituted and both planar and three-dimensional effects can be achieved. For instance, for a vase, a real object, Making the shape like a human face is also a feasible solution. If we take triangles as an example, the blank triangular part can be used as the design of the door opening. Or designers can use transparent materials as the surface of the table.

### 3.3.4.2 Poggendorff illusion

The Poggendorff illusion is named after Johann Christian Poggendorff, shown in Figure 3.41. If a straight line disappears at a certain angle on the surface of an entity and then immediately reappears on the other side of the entity, it will appear somewhat "misaligned". In the figure, the broken orange line is the same line. The blue is the modified line. After passing through the grey blocks, the blue line looks more in line with the orange lines (Greist&Schiffman, 1981).



Figure 3.41 Poggendorff illusion

#### **Illusion condition**

This illusion is similar to the Zollner illusion mentioned in Section 3.3.3.2. However, the Poggendorff illusion is a single example.

#### **Design element transformation**

Designers can consider using the Poggendorff illusion in the horizontal direction. Line segments can be used as supporting legs. Square coverings can serve as a layer of furniture. This design can make the table legs appear misaligned.

### 3.3.5 Fake three-dimensional feeling

By means of perception, objects can produce 3D or three-dimensional effects. This method can help make the furniture more vivid. Making fixed furniture has a different effect when moved or when the viewer moves. This can be achieved in a complex way or a simple way.

#### 3.3.5.1 Color Contrast

Creating 3D visual effects through color contrast essentially guides the viewer's brain to automatically interpret spatial layers by enhancing the relationship between light and shade, edge distinction, and spatial depth perception.



Figure 3.42 Three-dimensional square.

As shown in Figure 3.42,, different shades of orange form a seemingly three-dimensional cube. Different colors highlight the edges. The influence of light on different faces of a cube in reality was simulated.

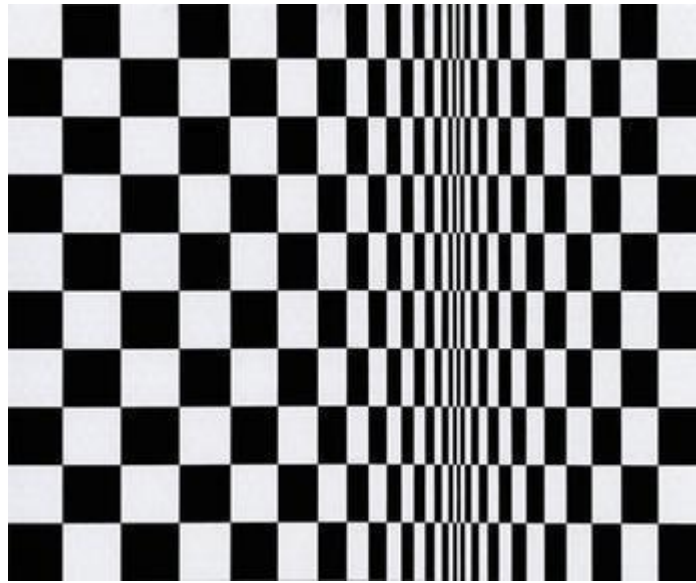


Figure 3.43 Movement in Squares, by Bridget Riley (1961)

As shown in Figure 3.43, By using high-contrast black and white, the edges are highlighted to create the presence of contour lines. These lines combine together to form a network structure. Then, perspective is used to simulate the indentation shape of the non-existent grid structure.

### **Illusion condition**

Designers can use high-contrast colors at the edges of objects (such as the junction of bright surfaces and shadows) to enhance the clarity of the edges and strengthen the "prominence" of the contours.

### **Design element transformation**

In order to highlight the fake 3D effect, designers can design on a flat surface, for example, a door and a desktop.

### 3.3.5.2 Perspective

By using the method of perspective, the furniture can be placed at different angles. The observed appearance undergoes different changes.

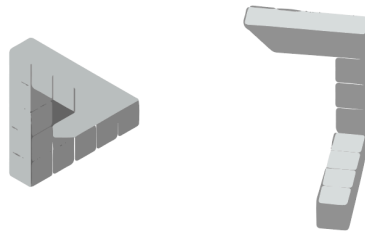


Figure 3.44 Impossible triangle

As shown in Figure 3.44, viewed from one angle, this triangle seems to be connected together, an impossible shape. But when the viewer shifts to another angle, they will find that they are actually separate

Through the method of perspective, we can first create the appearance the designers want in real 3D. Then designers connect the desired outline to the same point from the angle being observed through lines. Then designers can fill in the gaps between the lines. When finished, designers will get what is wanted from the desired observation angle. The Ames Room in section 2.2.4 is an example.

#### **Illusion condition**

From a certain observation of an angle, the effect that the designer intends to present can be seen.

#### **Design element transformation**

This design emphasizes perspective. All effects will be confined to a specific perspective of observation. However, in most cases, people use furniture at specific angles. So there is room for designing furniture by using perspective.

For example, designers can first use their own eyes as vanishing points. Then they place the desired pattern in the position where the furniture is located, then connecting the key parts backward from the vanishing point, As shown in Figure 3.45.

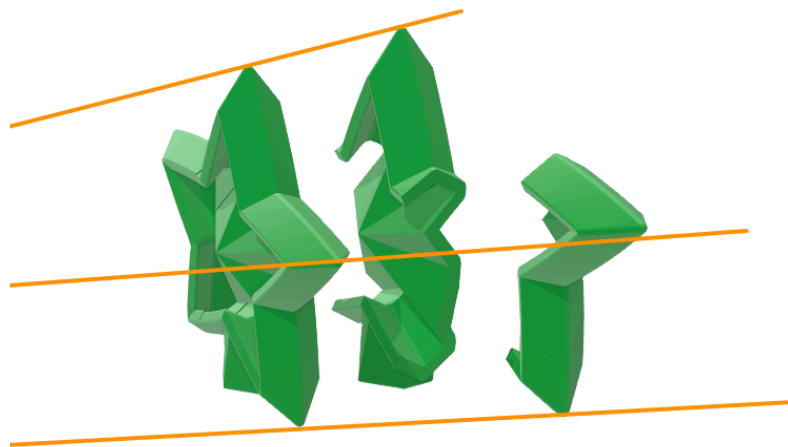


Figure 3.45 Star perspective

Finally, designers fill in different parts within the line as shown in Figure 3.45. Designers can obtain the desired pattern at the observation point as shown in Figure 3.46. But in fact, from other angles we can see the true appearance, shown in Figure 3.47.



Figure 3.46 Star in point

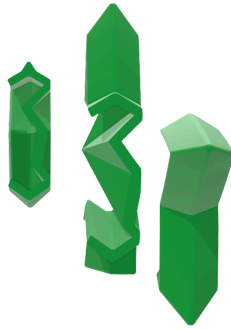


Figure 3.47 Star on the side

## **Chapter 4 Practical application**

### 4.1 Overview

This chapter will serve as a demonstration of the practical application of the design tools in this thesis by applying some illusion methods through the proposed design tool. This demonstrated process will encompass the entire range of design ideas and procedures in the design tools, describing in detail the situation of each step when a designer employs the guidelines in practical application to help designers better understand design tools.

### 4.2 Application

This chapter will simulate the process by which a designer uses the proposed design tools to expand inspiration for cabinet design. This demonstration helps designers understand how to use the guidelines in actual operation and understand the role of each process. Through this chapter, designers will have a better understanding of design tools, which will help them better obtain design inspiration, as well as learn how to make furniture more visually attractive in actual operation.

#### 4.2.1 Background

The hypothetical situation for this chapter is that of a designer wanting to design a cabinet through this design tool. The cabinet is presented as a rectangle. The design doesn't need to be overly complicated, but it should have a certain visual appeal. The designer wants to explore design possibilities through this design tool and develop a better design plan.

#### 4.2.2 Application

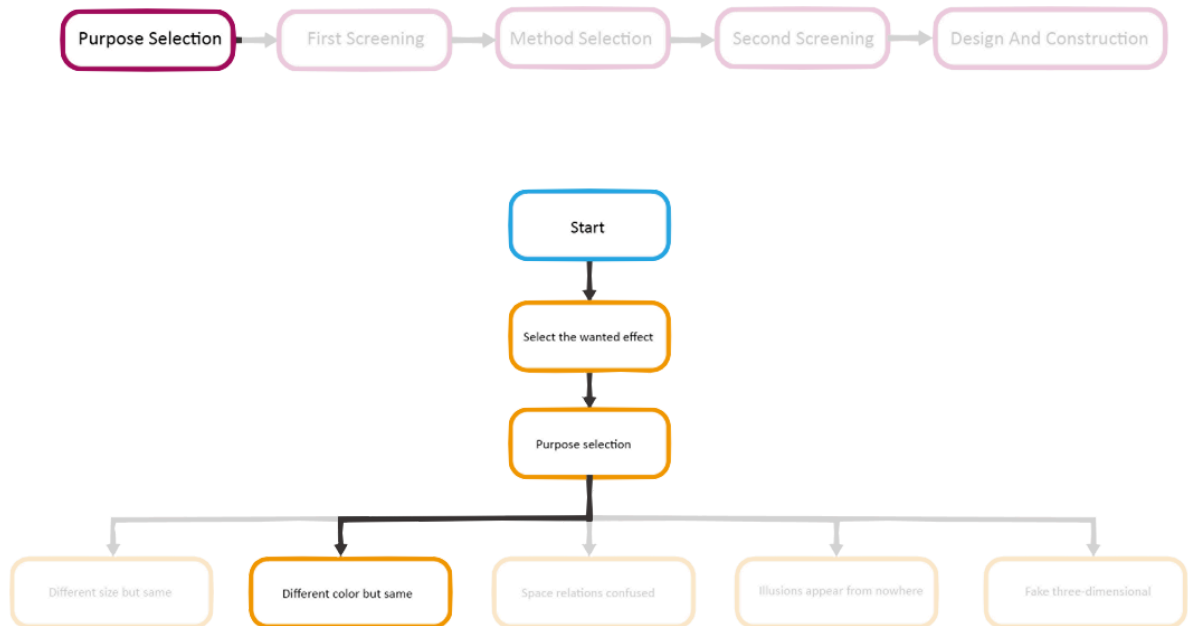


Figure 4.1 Designer in Purpose selection

The designer enters the first stage, Purpose Selection.

Among all the design purposes, the designer chose to use color as the main visual effect (Figure 4.1) Because this designer doesn't want the design to be overly complicated, and color, as a convenient manufacturing method, is very much in line with the designer's current requirements.

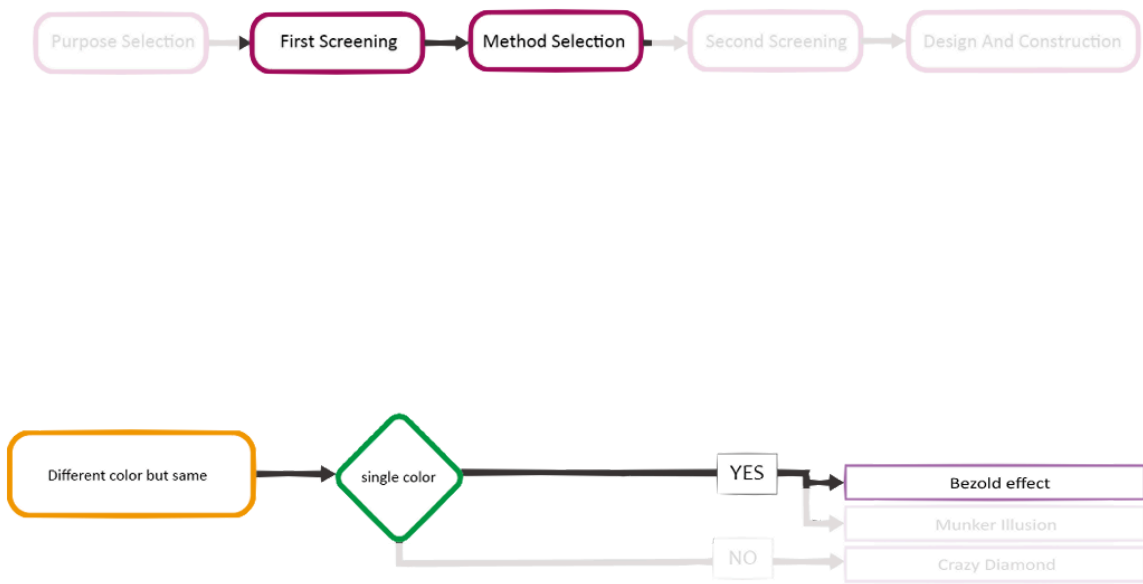


Figure 4.2 Designer in First Screening and Method Selection

After choosing the color as the design purpose, the designer is going to conduct the First Screening and decides to use a single color as the main contrast technique. The First Screening leads designers to Method Selection. In this Method Selection, the options are:

- Bezold effect
- Munker Illusion

The designer chose the Bezold effect as the scheme for the first attempt (Figure 4.2).

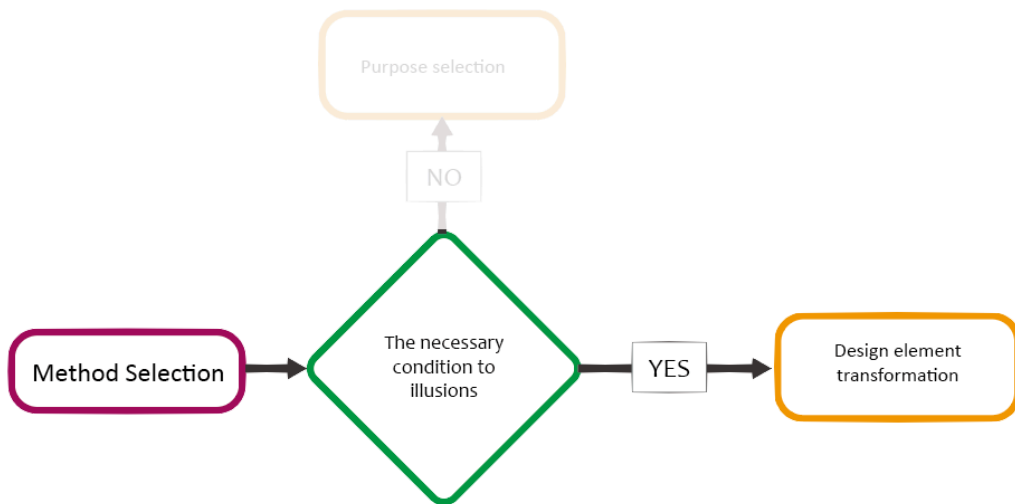


Figure 4.3 Designer in Second Screening

Through the understanding of the illusion content of the Bezold effect, if a simple cabinet is to be made, the designer believes that there is no part in the conditions of this illusion that conflicts with his idea. The selection decision of the Bezold effect was retained in the Second Screening and moved on to the next stage (Figure 4.3).

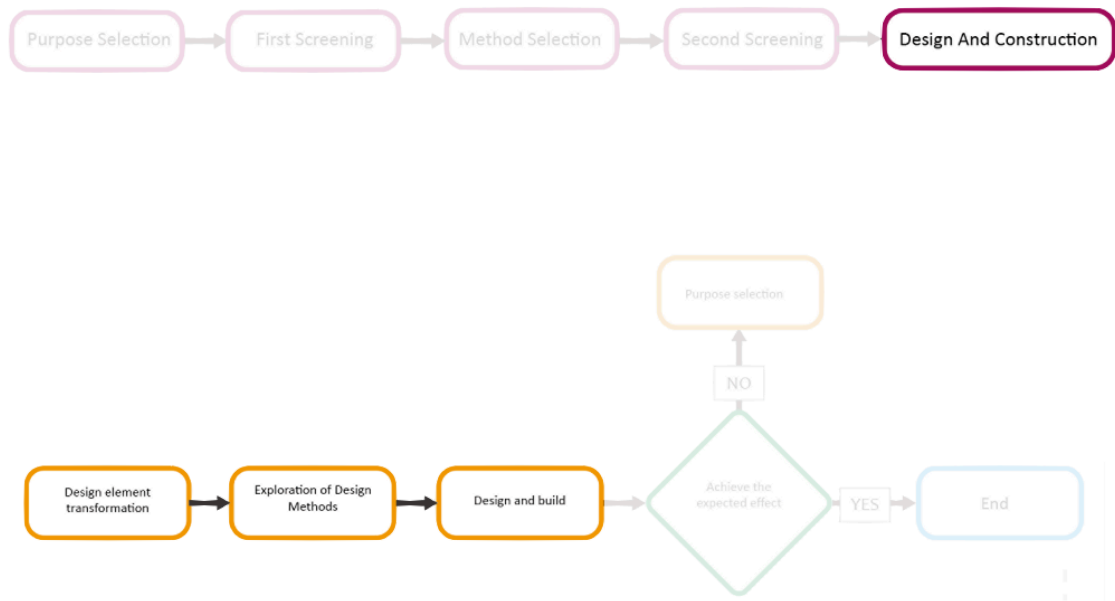


Figure 4.4 Designer in Design Stage

In the Design element transformation (Figure 4.4), designers draw inspiration from design recommendations. The designer thinks that the way the horizontal bars are arranged is very suitable for the sliding door used to close a cabinet. As shown in Figure 4.5, the designer decided to use two high-contrast colors, black and white, as the background colors, and then chose a light brown as the color to contrast with.

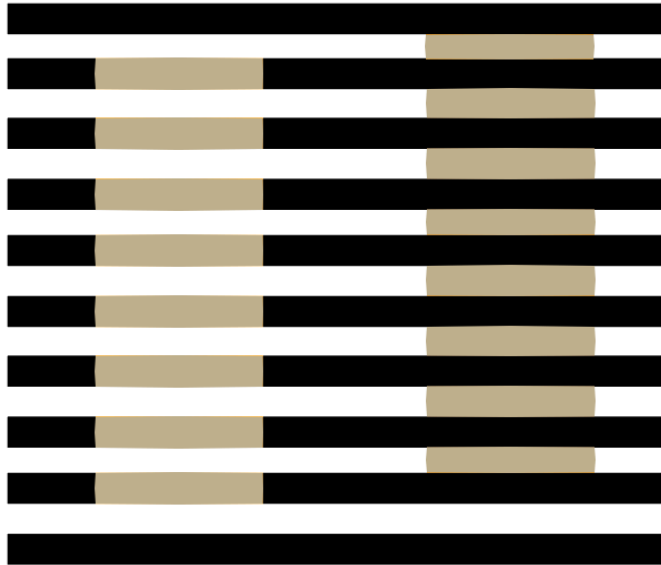


Figure 4.5 Designer edited Bezold effect

The designer has two light brown rectangles. A portion was cut and placed approximately in the center of the two door panels respectively. Then the highlighted bright and dark parts in this Bezold effect are added to the two different panels respectively. The designer used a square cabinet with a white sliding door opening and closing method. The designer applied the edited Bezold effect to the cabinet front as shown in Figure 4.6.

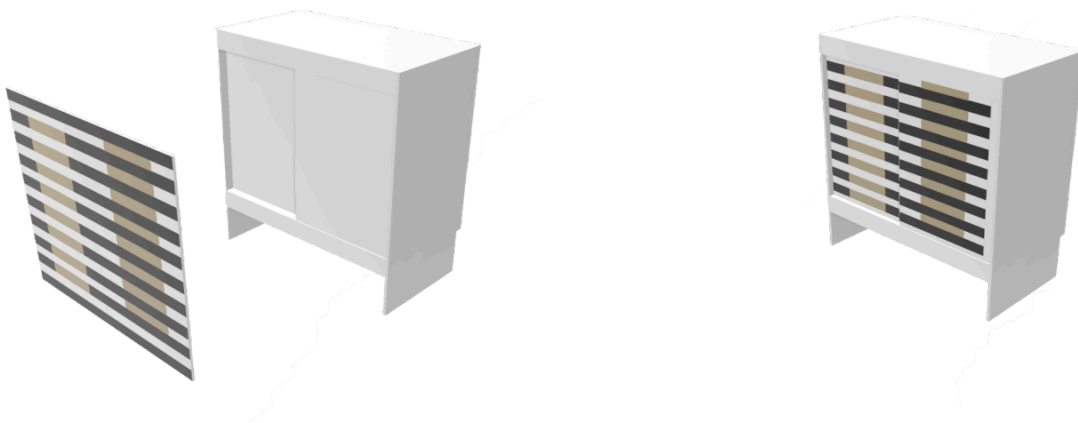


Figure 4.6 Designer edited Bezold effect in Cabinet

After a certain period of construction, the designer successfully created the pattern on the cabinet front.



Figure 4.7 Designer's Finished Cabinet

Because color is used as the design scheme, it is very easily influenced by other light and shadow in reality. The designer observed the effect after the production was completed.

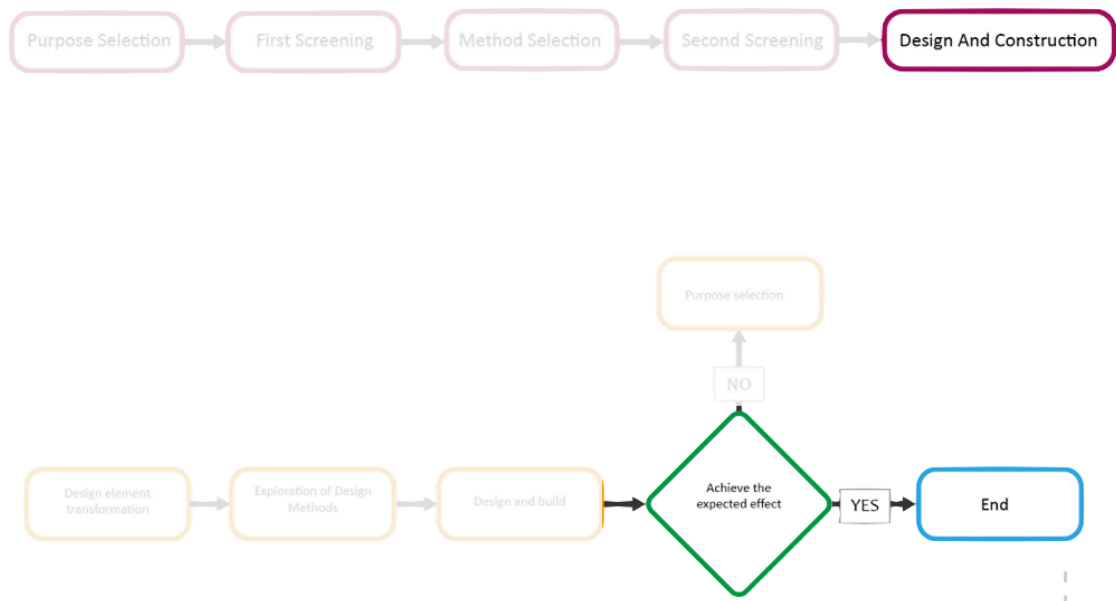


Figure 4.8 Designer in Construction

As shown in Figure 4.7, the light brown part is brighter in the area alternating with white and darker in the area alternating with black. The effect of this illusion matches the concept of the Bezold effect. The designer does not need to try another illusion (Figure 4.8). So the cabinet is completed using the Bezold effect.

#### 4.3 A Brief Introduction to Other Practical Cases of Furniture Design using Illusions

In the previous section 4.2.2, the steps for a designer to design a cabinet using design tools have been described in detail. This section will provide examples of some other applied illusions and related designs. This section only displays examples of the illusions used and the designs of furniture created using these misinterpretations, which help designers understand additional possibilities to demonstrate the extensibility of the proposed design tools. At the same time, this section helps designers better understand the design tools and perceive the effects presented on furniture, which enables designers to expand their inspiration.

##### 4.3.1 Example 1, Muller-Lyer Illusion

Using the Muller-Lyer Illusion (section 3.3.1.2) makes the originally square bookshelf even more distorted.

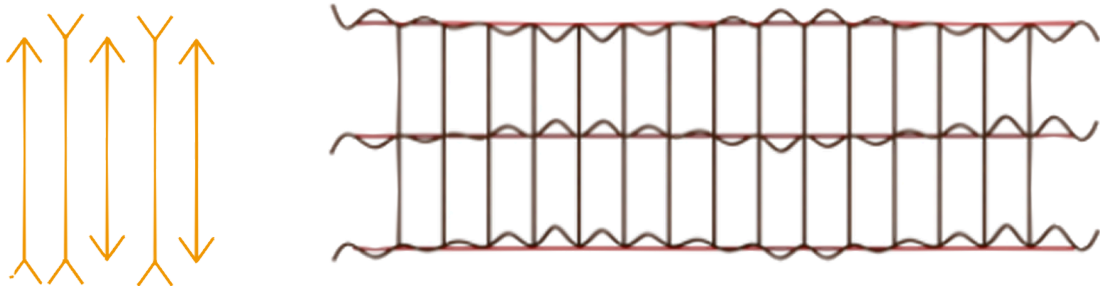
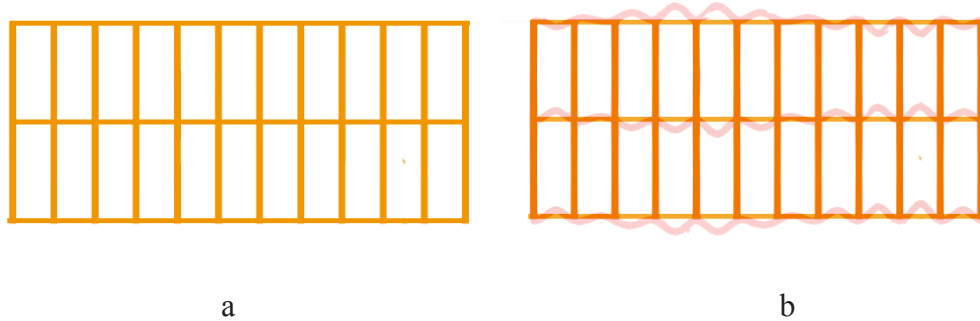


Figure 4.9 Arranging Muller-Lyer Illusion

After arranging the illusions as shown in Figure 4.9, the vertices are connected and bent, with the cross-section extended. In observing the height of the partitions between each layer of this bookshelf, they all seem different. However, due to the presentation of this illusion, in fact, all these long heights are the same.



Figure 4.10 Muller-Lyer Illusion Bookshelf



a

b

Figure 4.11 Compare Muller-Lyer Illusion

Figure 4.11 compares the furniture that uses Muller-Lyer Illusion (Figure 4.11, b) with the original furniture (Figure 4.11, a). Furniture that uses Muller-Lyer Illusion appears more dynamic while maintaining the same height intervals.

#### 4.3.2 Example 2, Fake Perspective Curves

Using high-contrast colors creates fake perspective curves on the plane of the long stool, thereby creating a fake 3D effect. Although the effect is visually presented by lines, in fact,

the principle is to produce the effect through black and white, as explained in the section which discussed how the use of colors can create a 3D visual impact.

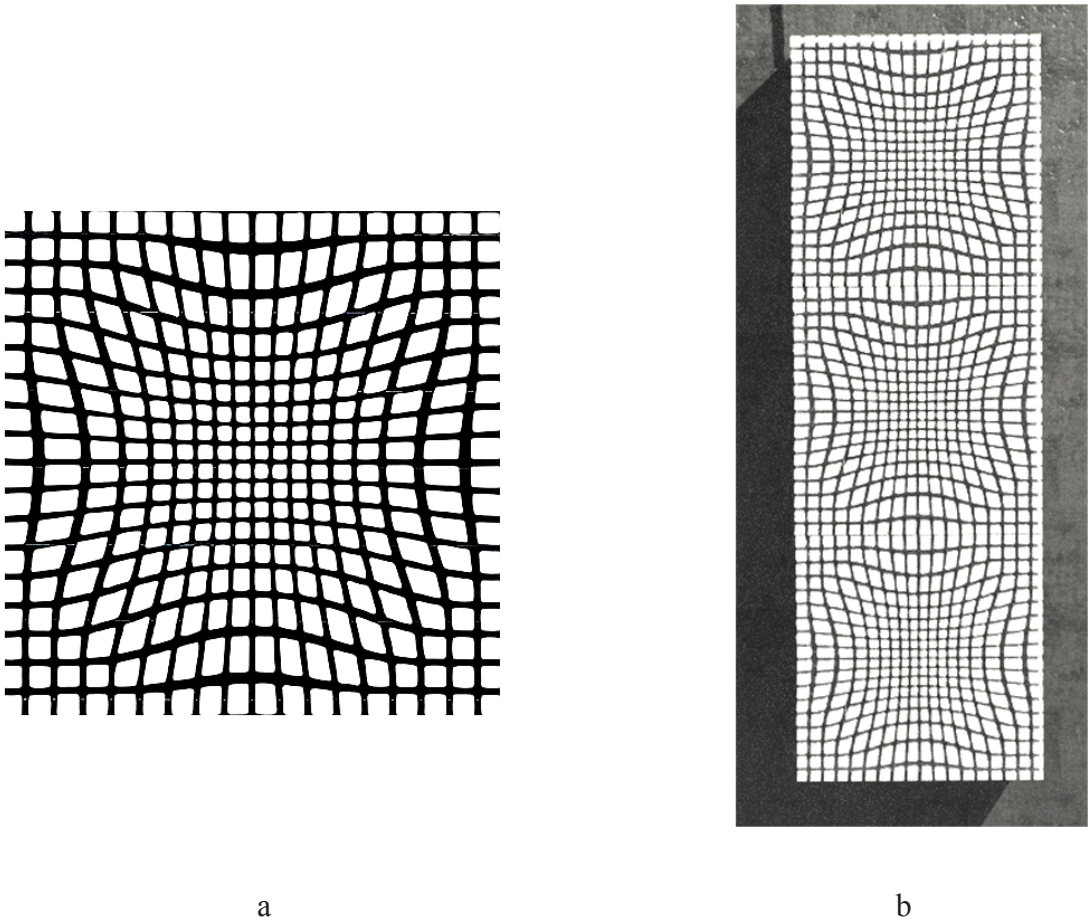


Figure 4.12 Curves To Bench

To achieve this perspective effect, the designers used line segments to simulate the feeling of a concave plane (Figure 4.12, a). Then this pattern is placed on a flat surface(Figure 4.12, b), making the black line appear as a groove. Under the illumination of light, black shadows will appear in the gaps, contrasting with the color of the surface.

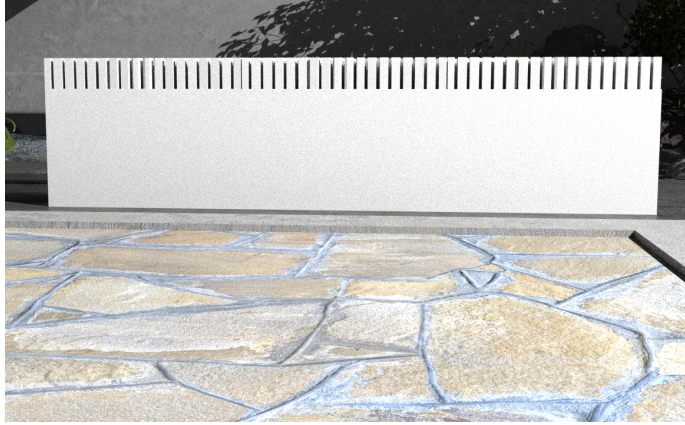


Figure 4.13 Front view of Bench

In this way, when the observer observes at an angle horizontal to the side of this bench (Figure 4.13), the top of the bench is a horizontal plane, but when the observer is there, a concave visual effect can be produced. When multiple patterns are spliced together, there is a wavy feeling (Figure 4.14). This method can be used to create 3D dynamic effects on flat objects.

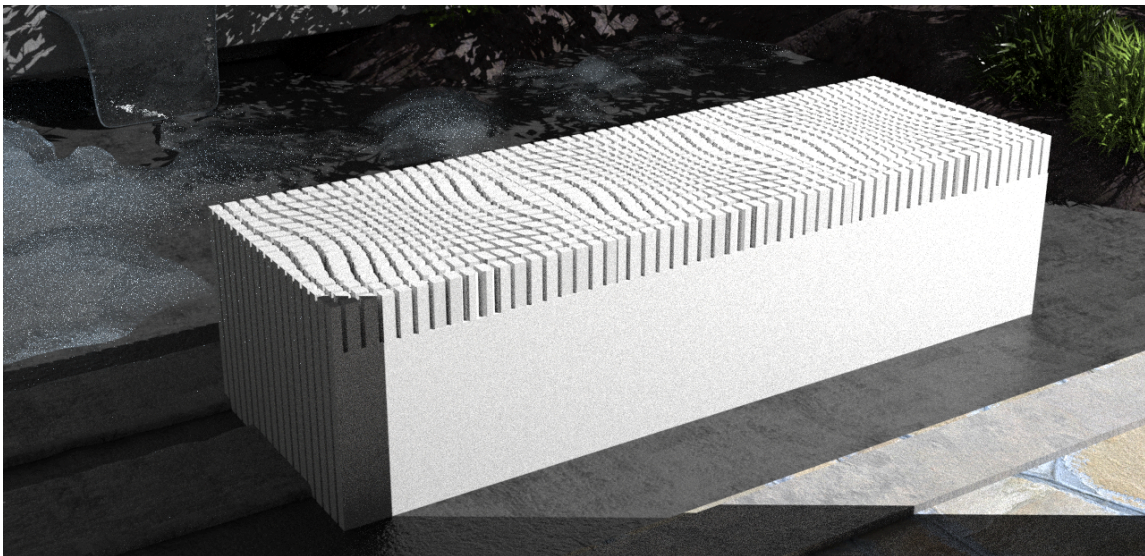


Figure 4.14 Hero view of Bench

### 4.3.3 Example 3, Fake 3D Color Chair

This example also uses the principles in section 3.3.5.1. Using color blocks with different contrasts to create fake 3D shadows gives the chair an unusual three-dimensional effect.



Figure 4.15 Colored Cube

This example simulates the color changes produced by a cube (Figure 4.15) under light in real life through different color depths.

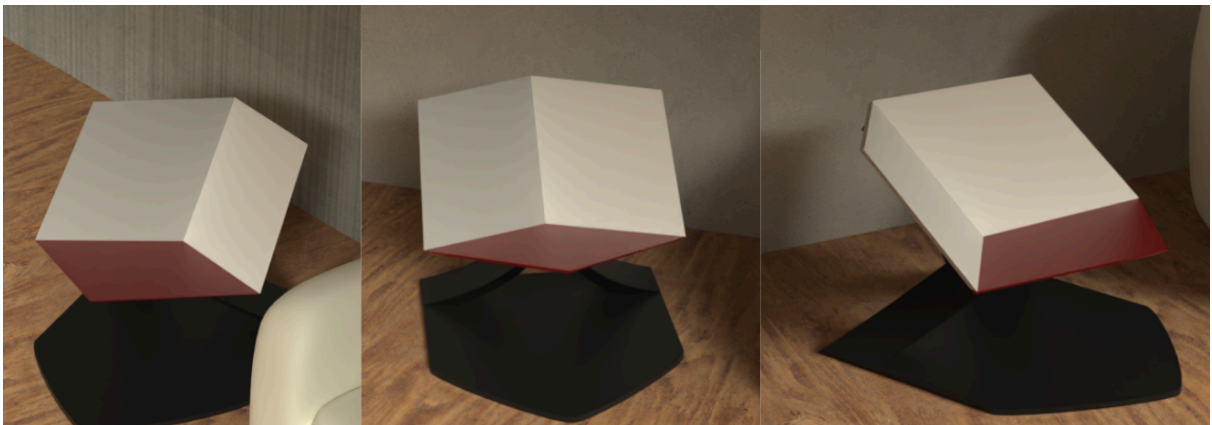


Figure 4.16 Colored Chair in angle

The chair has three panels. The designers placed the three simulated colors on the three panels respectively,, then tilted each side of this chair at a certain angle. When an observer walks past this chair (Figure 4.16), people will have different perceptions when viewing it from different angles.

#### 4.3.4 Example 4, Orbison Illusion Cabinet

This example uses the Orbison illusion in section 3.3.3.1 for the surface of the cabinet door panel. The effect causes the straight lines to distort and gives the cabinet a dynamic effect.

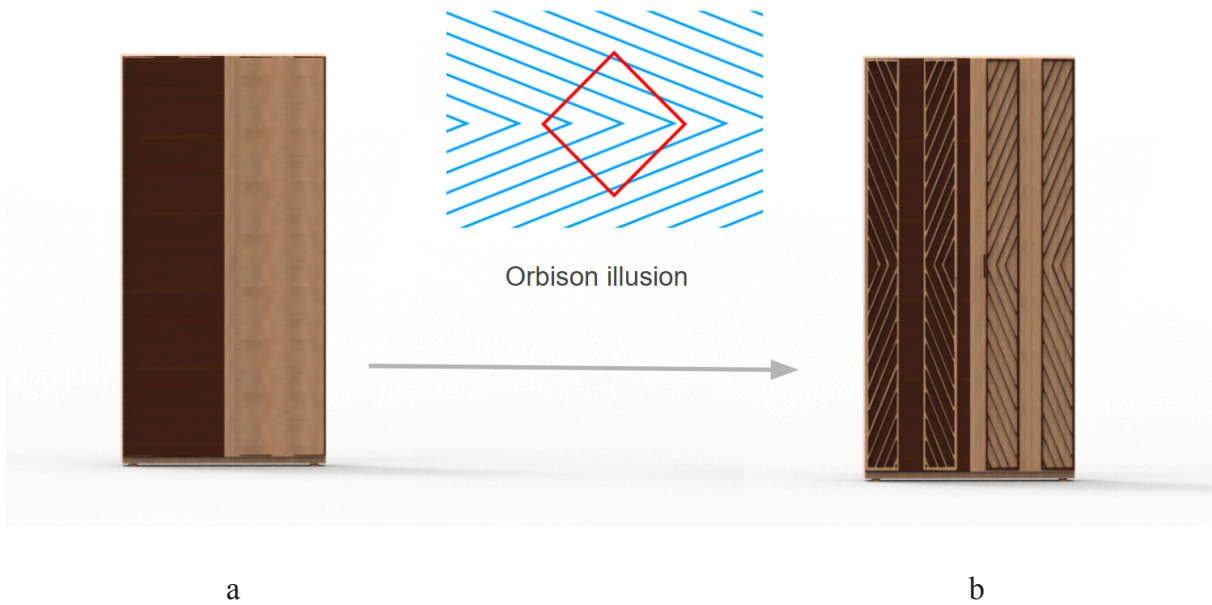


Figure 4.17 Orbison Illusion Cabinet Transformation



Figure 4.18 Full view of Cabinet

First, the designer extracts and expands the rectangle in the Orbison Illusion, then keeps the diagonal lines in the rectangle. After obtaining the pattern, the designer applies it to the

surface of the cabinet door and uses different colors to make the pattern stand out (Figure 4.17, b). Superficially, the door panel of the cabinet seems to be distorted (Figure 4.18). This method only requires the addition of decorative pieces to create dynamic effects on the originally simple panel (Figure 4.17, a), and there is no need to truly distort any straight lines.

#### 4.3.5 Example 5, Zollner Illusion Bookshelf

The Zollner illusion in 3.3.3.2 Fringe Edge Illusion makes the actual parallel straight lines appear not parallel.

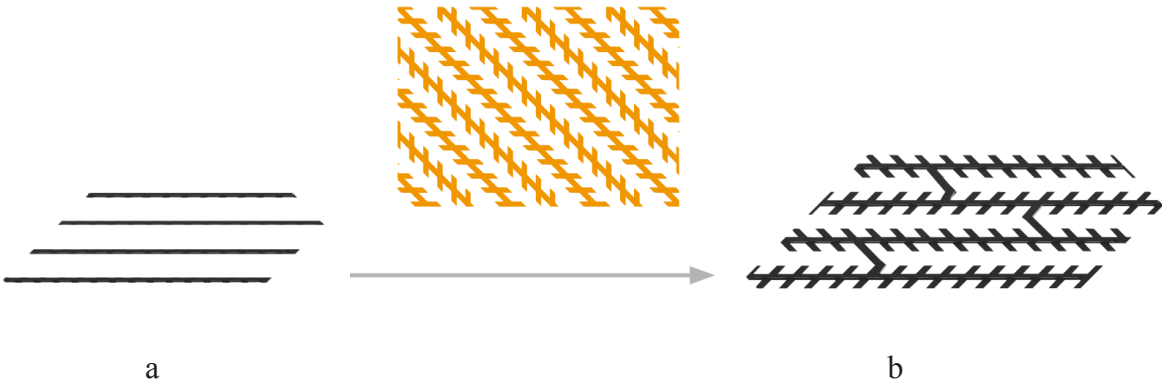


Figure 4.19 Zollner Illusion Bookshelf Transformation

The originally parallel straight lines (Figure 4.19, a ) are perceptually shifted to have an inclined effect through Zollner illusion, appearing visually inclined (Figure 4.19, b ), but in fact are straight.

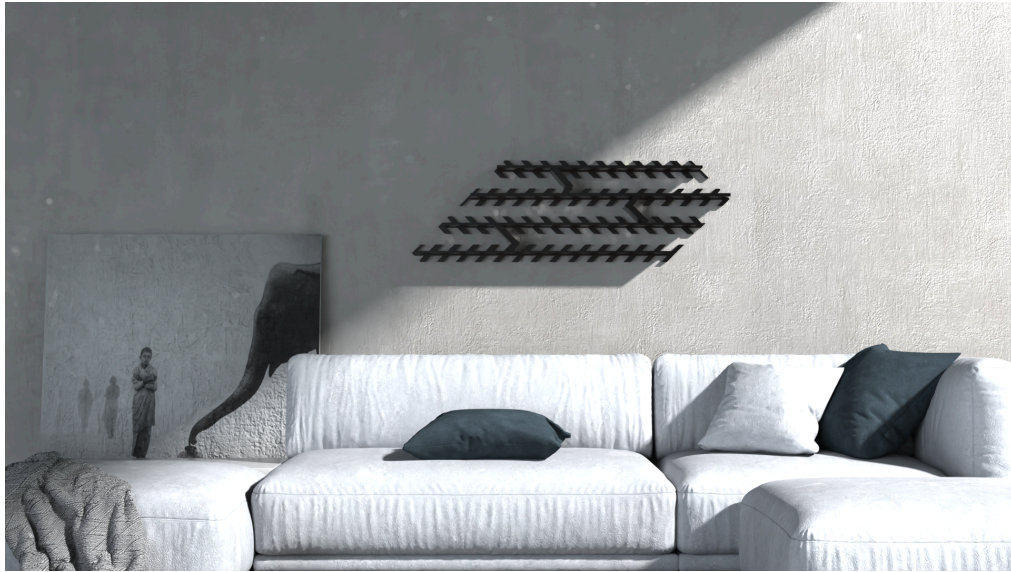


Figure 4.20 Bookshelf in living room

However, this illusion that requires high contrast is easily affected by the perspective and light and shadow in actual operation. Perspective and light and shadow may cause features to disappear or not stand out. This will cause the effect of the illusion to decline. However, furniture is mostly in a fixed direction when in use. As shown in the perspective in Figure 4.20, the Zollner Illusion, which has better effect in 2D, can also be effectively applied to furniture to a certain extent.

#### 4.4 Summary

This chapter demonstrates how a designer uses this design tool to apply perception in furniture design. Due to space limitations, this chapter only presents a design idea for some illusions and some furniture. No in-depth exploration was conducted on other illusions and furniture. In practical applications, this method can not only help designers expand their design ideas, but also make their furniture designs more visually attractive after using the perpetual method.

## Chapter 5 Conclusion

Based on the research in Chapter 2, designers will discover an expandable design opportunity combining perception theories and principles with furniture design. Doing so integrates perception as a design inspiration into furniture design to create visually appealing furniture. Designers need a systematic approach to achieve this goal. Having this approach can not only expand their design ideas with the help of design tools, but also make their furniture have a unique visual appeal.

Through the research in Chapter Two, designers will benefit from a design tool that helps them expand their existing design ideas and apply perceptual principles to furniture design, making it more visually appealing.

Chapter Three provides a design tool that encompasses all aspects of the furniture design process. This chapter discusses different illusions, explaining each effect within the context of the given design tools. The chapter discusses how illusions can be integrated into furniture design to make it more visually attractive by providing a classification and transformation of each illusion through the process from prototype design to final verification.

Designers choose transformations based on the illusions they have selected, therefore designing a complete piece of furniture with the chosen illusion effect. The entire process provides valuable references for subsequent practical applications so that designers can carry out design work in the system, ensuring that the perceptions they have chosen can be effectively integrated into furniture design to enhance the visual appeal of their furniture.

In Chapter Four, the design tools proposed in Chapter Three will be explained and demonstrated through a hypothetical project explained in detail from the initial screening to the final design: selection, integration and transformation, construction and improvement, to final design. The example project incorporates an illusion chosen by a designer into the

design of a cabinet. Among available options, the designer chose the Benzo illusion. This chapter helps readers understand each stage of the proposed design process through detailed explanations and demonstrations, providing practical design methods and inspirations.

Through this research. Designers can know that perception has great potential for development in furniture design. Perception can serve as a design inspiration and be applied in home design to endow furniture with different visual appeal. However, there are still some problems that cannot be solved in this study.

### 5.1 Further research

Although this study provides designers with a systematic set of design tools, there are still some areas worthy of further exploration.

The illusions provided in this study have some inevitable problems in application. For instance, some illusions place a strong emphasis on the 2D presentation effect, but in reality, they are easily disturbed by multiple factors in reality, such as light and shadow and perspective, which leads to a decline in their effect. In the future, these negatives can be optimized through further research and development.

This study mainly focuses on a number of selected illusions. In the future, the guidelines can be expanded to excluded or unknown illusions. How to utilize new, different illusions in furniture design remains a potential challenge.

In this study, the design tools offer numerous different illusion schemes, but the illusion tools provide individual design methods and suggestions. The integration and usage of multiple illusions have not been explored, which can become a direction for future development and research.

## References

- Ackerman, James S. (1994). *Distance Points: Essays in Theory and Renaissance Art and Architecture*. MIT Press.
- Albers, J. (1963). *The Interaction of Color*. Yale University Press, New Haven., CT: 1963.  
<https://archive.org/download/interaction-of-color-50th-anniversary-edition/9780300179354.pdf>
- Alberti, L. B. . (1804). Alberti's diagram showing perspective lines leading to a vanishing point in Della Pittura.  
<https://archive.org/stream/dellapitturaedel00albe#page/n177/mode/2up>
- Aliwiki. (2006)). Image illustrant le phénomène de la bande de Mach,[https://commons.wikimedia.org/wiki/File:Bandes\\_de\\_mach.PNG](https://commons.wikimedia.org/wiki/File:Bandes_de_mach.PNG)
- Ames, A. (N.d.). <https://ar.inspiredpencil.com/pictures-2023/ames-room-illusion>
- Arnheim, R. (1972). *Art and visual perception: A psychology of the creative eye*. University of California Press.  
<https://archive.org/details/art-and-visual-perception-rudolf-arnheim/page/n21/mode/2up>
- Arnheim, R. (2004). *Art and Visual Perception*. University of California Press.  
<https://archive.org/details/art-and-visual-perception-rudolf-arnheim>
- Bach, M., & Poloschek, C. M. (2006). "Optical Illusions." *Advanced Clinical Neuroscience Rehabilitation*. 6 (2): 20–21. Archived from the original (PDF) on 2021-01-20.
- Bertamini, M. & Wade, N. (2023). Mario Ponzo (1928) on Perception of Numerosity: A Translation and Commentary. *Perception*, 52 (8): 545–575.

Brody, Richard (2012, July 12). The inadequacy of Berlin's "Memorial to the Murdered Jews of Europe." *The New Yorker*.

<https://www.newyorker.com/culture/richard-brody/the-inadequacy-of-berlins-memorial-to-the-murdered-jews-of-europe>

Brunelleschi, F. (2023). Perspective Theory..

<https://ar.inspiredpencil.com/pictures-2023/linear-perspective-brunelleschi>

Bulatov, A., Bertulis, A., Mickienė, L., Surkys, T., & Bielevičius, A. 2011).Contextual flanks' tilting and magnitude of illusion of extent. *Vision Research*. 51 (1): 58–64.

Cohen, R.A. (2011). Lateral Inhibition. In: Kreutzer, J.S., DeLuca, J., Caplan, B. (eds) *Encyclopedia of Clinical Neuropsychology*. Springer, New York, NY.

[https://doi.org/10.1007/978-0-387-79948-3\\_1379](https://doi.org/10.1007/978-0-387-79948-3_1379)

Cohen, R.A. (2011). Lateral Inhibition. In: Kreutzer, J.S., DeLuca, J., Caplan, B. (eds) *Encyclopedia of Clinical Neuropsychology*. Springer, New York, NY.

[https://doi.org/10.1007/978-0-387-79948-3\\_1379](https://doi.org/10.1007/978-0-387-79948-3_1379)

Colman, Andrew M. (2006). "Sander parallelogram n.". *A Dictionary of Psychology*. Oxford University Press.

Cooper, M.R., Runyon, R.P., Tatz, S.J. et al. (1972). The Sander illusion as a function of relative space and component lines. *Perception & Psychophysics II*, 102-104

<https://doi.org/10.3758/BF03212695>

Cornsweet, T. (1970). *Visual Perception*. New York: Academic Press.

Cucker, F. (2013). *Manifold Mirrors: The Crossing Paths of the Arts and Mathematics*. Cambridge University Press.

Da Vinci, L. (2025). *The Last Supper*.

<https://www.italy-villas.com/to-italy/2025/localities/milan/visit-the-last-supper-2025>

Dorward, F.M. & Day, R.H. (1997) Loss of 3-D shape constancy in interior spaces: the basis of the Ames-room illusion. *Perception*. 26(6):707-18. doi: 10.1068/p260707. PMID: 9474341.

Ehrenstein, W. (1941). Über Abwandlungen der L. Hermannschen Helligkeitserscheinung (Modifications of the Brightness Phenomenon of L. Hermann). *Zeitschrift für Psychologie*, 150: 83–91

Emcke, Von Carolin; Berg, Stefan (2005, May 2). Remembering the Holocaust: Extracting Meaning from Concrete Blocks. *Der Spiegel*. Hamburg. Retrieved 16 December 2016. <https://www.spiegel.de/international/spiegel/remembering-the-holocaust-extracting-meaning-from-concrete-blocks-a-354837.html>

Fish, W. (2021). *Philosophy of Perception: A Contemporary Introduction* (2nd ed.). Routledge. <https://doi.org/10.4324/9781351049504>

Françai .(2006 Mach band illusion.

,[https://en.wikipedia.org/wiki/Mach\\_bands#/media/File:Bandes\\_de\\_mach.PNG](https://en.wikipedia.org/wiki/Mach_bands#/media/File:Bandes_de_mach.PNG)

Fraser spiral illusion. (n.d.).[https://en.wikipedia.org/wiki/Fraser\\_spiral\\_illusion](https://en.wikipedia.org/wiki/Fraser_spiral_illusion).

Fraser, J.. (1908). A new visual illusion of direction. *British Journal of Psychology*. 2 (3): 307–320. doi:10.1111/j.2044-8295.1908.tb00182.x.

Gandhi, ,T., Kalia, A., Ganesh, S., & Sinha,, P. (2015). Immediate susceptibility to visual illusions after sight onset. *Current Biology*,25(9):R358-9. doi: 10.1016/j.cub.2015.03.005.

- Gartner, P. (1998). *Brunelleschi* (in French). Cologne: Konemann
- Geier, J., & Hudák, M. (2011). Changing the Chevreul Illusion by a Background Luminance Ramp: Lateral Inhibition Fails at Its Traditional Stronghold - A Psychophysical Refutation. *PLoS One*. 6 (10): e26062. doi:10.1371/journal.pone.0026062.
- Gombrich, E. H. (1994). *Art and illusion: A study in the psychology of pictorial representation*. Princeton Univ. Press.
- Gombrich, L., Gombrich, E. H., & New York University. (1994). *The Sense of Order: A study in the psychology of decorative art (The Wrightsman Lectures, V. 9)* (2nd Revised ed.). Phaidon Press. <https://archive.org/details/senseoforderst00gomb>
- Gregory, R. L. (1968). *Eye and Brain: The Psychology of Seeing*. Weidenfeld & Nicolson.
- Gregory, R. L. (1997). Knowledge in perception and illusion. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 352(1358), 1121–1127. <https://doi.org/10.1098/rstb.1997.0095>
- Gregson, R. A. (1995). *Cascades and Fields in Perceptual Psychophysics*. World Scientific Publishing Co.
- Greist-Bousquet S. & Schiffman H.R. (1981). The Poggendorff illusion: An illusion of linear extent?. *Perception*. 10 (2): 155–64. doi:10.1068/p100155.
- Happold B. & Dziubak, P. (N.d.) Memorial to the Murdered Jews of Europe, Berlin, Germany. <https://www.burohappold.com/projects/memorial-to-the-murdered-jews-of-europe/>
- Hering Illusion. (n.d.). [https://en.wikipedia.org/wiki/Hering\\_illusion](https://en.wikipedia.org/wiki/Hering_illusion)

- Hering, E. (1861). Beiträge zur Physiologie. I. Zur Lehre vom Ortssinne der Netzhaut. Leipzig: Engelmann.
- Howe C. Q. & Purves, D. (2005). The Müller-Lyer illusion explained by the statistics of image-source relationships. *Proceedings of the National Academy of Sciences of the United States of America*. 102 (4): 1234–1239. doi:10.1073/pnas.0409314102.
- Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of Physiology*, 160(1), 106–154. DOI: 10.1113/jphysiol.1962.sp006837.
- Kanizsa, G (1955), Margini quasi-percettivi in Campi con stimolazione omogenea. *Rivista di Psicologia*, 49(1):7–30
- Kanizsa, G., Legrenzi, P., & Bozzi, P. (1979). *Organization in Vision : Essays on Gestalt Perception*. Praeger.
- Kemp, M. (1990). *The science of art: Optical themes in Western art from Brunelleschi to Seurat*. Yale University Press. <https://archive.org/details/scienceofartopti0000kemp>
- Khalil, E. L. (2021). *Why Does Rubin's Vase Differ Radically From Optical Illusions? Framing Effects Contra Cognitive Illusions*. *Frontiers in Psychology*, 12, 597758. <https://doi.org/10.3389/fpsyg.2021.597758>
- Kitaoka, A. (2003). Rotating snakes: A new class of visual illusion. *Perception*, 32(Suppl.), 15. DOI: 10.1068/p32sbe1.
- Kitaoka, A., & Ishihara, M. (2000). *Three elemental illusions determine the Zöllner illusion*. *Perception & Psychophysics*, [https://www.psy.ritsumei.ac.jp/akitaoka/ZollnerPP.pdf?utm\\_source=chatgpt.com](https://www.psy.ritsumei.ac.jp/akitaoka/ZollnerPP.pdf?utm_source=chatgpt.com)

Koffka, K. (1935). *Principles of Gestalt Psychology*. Harcourt, Brace & World.

<https://archive.org/details/in.ernet.dli.2015.7888/page/n15/mode/2up>

Künnapas, T. M. (1955). An analysis of the “vertical-horizontal illusion”. *Journal of Experimental Psychology*, 49(2), 134–140.

Leonard, J. (2018, January 12). The Optical Illusions That Make the Parthenon Perfect.

<https://www.greece-is.com/the-optical-illusions-that-make-the-parthenon-perfect/>

Lin, S.-S., Morace, C. C., Lin, C.-H., Hsu, L.-F., & Lee, T.-Y. (2018). Generation of Escher Arts with Dual Perception. *IEEE Transactions on Visualization and Computer Graphics*, 24(2),

1103–1113. [https://www.researchgate.net/publication/313022839\\_Generation\\_of\\_Escher\\_Arts\\_with\\_Dual\\_Perception](https://www.researchgate.net/publication/313022839_Generation_of_Escher_Arts_with_Dual_Perception)

Livingstone, M., & Hubel, D. (1988). Segregation of form, color, movement, and depth: Anatomy, physiology, and perception. *Science*, 240(4853), 740–749. DOI: 10.1126/science.3283936.

Lockal.(2007). Bezold effect Red with Black and

White. [https://en.wikipedia.org/wiki/Bezold\\_effect#/media/File:Bezold\\_Effect.svg](https://en.wikipedia.org/wiki/Bezold_effect#/media/File:Bezold_Effect.svg)

Lotto, R. B. The Cornsweet Illusion, Figure 2. ResearchGate. researchgate.net.

Masaccio. (1427) *The Trinity*

<https://www.britannica.com/topic/The-Trinity-painting-by-Masaccio>

Miller, G. A. & Isard, S. (1963).; Stephen Isard. Some perceptual consequences of linguistic rules. *Journal of Verbal Learning and Verbal Behaviour*. 2 (3): 217–228.

Müller-Lyer FC (1889). Optische Urteils Täuschungen [Optical Illusions]. *Archiv für Physiologie Supplement. 1889: 263–270.*

NASA. (N.d.). Cydonia, Viking 1

[https://it.wikipedia.org/wiki/Cydonia\\_Mensae#/media/File:Martian\\_face\\_viking\\_cropped.jpg](https://it.wikipedia.org/wiki/Cydonia_Mensae#/media/File:Martian_face_viking_cropped.jpg)

Nicholas, J.; Sakurai, K., & Gyoba, J. 2007). Whither Wundt. *Perception. 36* (2): 163–166. doi:10.1068/p3602ed.

Ninio, J. (2014). Geometrical illusions are not always where you think they are: a review of some classical and less classical illusions, and ways to describe them. *Frontiers of Human Neuroscience, . 8*:856. doi: 10.3389/fnhum.2014.00856.

Norman, D. A. (2005). *Emotional Design: Why We Love (or Hate) Everyday Things* (1st ed.). Basic Books.

Notre Dame de Paris. (2016). *Notre Dame De Paris Tour*

*Guide.* <http://travelinnate.com/notre-dame-de-paris/>

Olsen, C. (2013). Escher, M.C. Sky and Water. c. 1938. woodcut. *The Art of M.C. Escher, The Art*

*Appreciation,* <https://theartappreciationblog.blogspot.com/2013/05/the-art-of-mc-escher.html>

Orbison illusion. (n.d.). [https://en.wikipedia.org/wiki/Orbison\\_illusion](https://en.wikipedia.org/wiki/Orbison_illusion)

Pantheon, 27 B.C., The Pantheon in Rome. (n.d.) <https://ouritalianjourney.com/pantheon/>

Pastor, A. (2005). Augmenting reality: On the shared history of perceptual illusion and video projection mapping. arXiv preprint, arXiv:2005.14317. <https://arxiv.org/pdf/2005.14317>

Persian Qum Rug, Khazai Rugs, The Historical Aspect of The Persian Rug.

(n.d.) <https://khazairugs.com/blog/history-of-persian-rug/>

Piero della Francesca - Pinacoteca di Brera. (n.d.)

<https://commons.wikimedia.org/w/index.php?curid=156305>

Ponzo, M. (1911). Intorno ad alcune illusioni nel campo delle sensazioni tattili sull'illusione di Aristotele e fenomeni analoghi. *Archives Italiennes de Biologie*.

Rashal, E., Cretenoud, A.F., & Herzog, M.H. (2020). Perceptual grouping leads to objecthood effects in the Ebbinghaus illusion. *Journal of Vision*, 20(8):11. doi: 10.1167/jov.20.8.11.

Rent, J. (2021). Optical illusions in the ancient architecture.

<https://imperiumromanum.pl/en/article/optical-illusions-in-the-ancient-architecture/>

Riley, B. (1961). Movement in squares.

[https://en.wikipedia.org/wiki/Op\\_art#/media/File:Riley,\\_Movement\\_in\\_Squares.jpg](https://en.wikipedia.org/wiki/Op_art#/media/File:Riley,_Movement_in_Squares.jpg)

Roberts, B., Harris, M.G., & Yates, T.A. (2005). The roles of inducer size and distance in the Ebbinghaus illusion (Titchener circles). *Perception*. 34 (7): 847–56. doi:10.1068/p5273.

Roeckelein, J. E. (2006). *Elsevier's Dictionary of Psychological Theories*. Amsterdam: Elsevier. . ISBN 9780444517500.

Roman cube mosaics 2nd centuries A.D, 20 Ancient Mosaic Quiz Questions for Christmas.

(n.d.) <https://helenmilesmosaics.org/ancient-mosaics-general/mosaic-quiz/>

- Roman, 2nd century CE, Roman cuboid mosaics 2nd centuries A.D, Mosaic floor panel,  
(n.d.) <https://www.metmuseum.org/art/collection/search/253565>
- Rubin, E. (1915). *Synsoplevede figurer: Studier i psykologisk analyse [Perceived figures: Studies in psychological analysis]*. Gyldendal, Nordisk Forlag.
- Schacter, D. L. (1982). *Stranger behind the Engram: Theories of Memory and the Psychology of Science*. Lawrence Erlbaum Associates.
- Schmidtman, G., Ouhnana, M., Loffler, G., & Kingdom, F. A. A. (2016). Imagining circles: empirical data and a perceptual model for the arc-size illusion. *Vision Research*, 121, 50-56. <https://doi.org/10.1016/j.visres.2015.12.003>,
- Schreiber, B. A. (n.d.). Chartres Cathedral Interior of Chartres Cathedral, France. Notre-Dame de Chartres, Chartres-Cathedral. Encyclopedia Britannica. <https://www.britannica.com/topic/Chartres-Cathedral>
- Shogo, I. 省吾 今井 (1960). Experiments On Jastrow Illusion, „Jastrow 錯視に関する実験”. *心理学研究. An experiment on the Jastrow illusion*. *Psychological Research* 30 (5): 350–356. doi:10.4992/jjpsy.30.350
- Spielman, R. M., Dumper, K., Jenkins, W., Lacombe, A., Lovett, M., & Perlmutter, M. (2020). *Psychology*. (N. Arduini-Van Hoose & P. Carroll, Ed.). Lumen Learning. Retrieved from <https://courses.lumenlearning.com/suny-hvcc-psychology-1> (Original work published 2014). CC-BY 4.0., Sensation and Perception, Introduction to Psychology, p260-342, <https://oerfiles.s3-us-west-2.amazonaws.com/Psychology/Introduction+to+Psychology.pdf>

- Von Helmholtz, H.. (1867/2005). *Treatise on physiological optics [Handbook of Physiological Optics]*. May 13, 2005, Dover Publications.
- Wade, N. (2018). The age of illusions. *The Psychologist, Cognition and Perception, History and Philosophy*. <https://www.bps.org.uk/psychologist/age-illusions>
- Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: II. Conceptual and theoretical foundations. *Psychological Bulletin*, 138(6), 1172–1217.
- Watanabe,, I. & Cavanagh,, P. (2012). Diamond Illusion with Isao Watanabe and Patrick Cavanagh, <https://anstislab.ucsd.edu/illusions/diamond-illusion/>
- Wertheimer, M. (1938). Laws of organization in perceptual forms. In W. D. Ellis (Ed.), *A Source Book of Gestalt psychology* . Kegan Paul, Trench, Trubner & Company.  
<https://doi.org/10.1037/11496-005>
- Wittkower, R. (1953). *Brunelleschi and 'proportion in perspective'*. *The Art Bulletin*, 35(2), 129-145. <https://doi.org/10.2307/750367>.
- Wundt illusion. (n.d.). [https://en.wikipedia.org/wiki/Wundt\\_illusion](https://en.wikipedia.org/wiki/Wundt_illusion)
- Yildiz, G.Y., Sperandio, I., Kettle, C., & Chouinard, P. A. (2019) The contribution of linear perspective cues and texture gradients in the perceptual rescaling of stimuli inside a Ponzo illusion corridor. *PLoS One*, 14(10):e0223583. doi: 10.1371/journal.pone.0223583.
- Zöllner, J. C. F. (1860). Ueber eine neue Art von Pseudoskopie und ihre Beziehungen zu den von Plateau und Oppel beschriebenen Bewegungsphänomenen [On a new type of pseudoscopy and its relation to the motion phenomena described by Plateau and Oppel]. *Annalen der Physik und Chemie*, 186(7), 500–523.

Zucker, S. & Harris, B. (2015).Linear perspective: Brunelleschi's experiment. *Smarthistory*.

<https://smarthistory.org/linear-perspective-brunelleschis-experiment/>.