THE IMPOSSIBLE VASE:
AN EXPLORATION IN PERCEPTION

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

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Master of Science

by

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ABSTRACT

The Impossible Vase is a digital installation combining elements of perception and computer graphics to create a unique visual experience through light projection. The projected images are cast upon solid objects rather than a traditional flat canvas. This installation will explore perceptual issues by deconstructing visual cues and analyzing the way our minds process visual information into a coherent story. The projected imagery, along with the movement of the three dimensional canvas, will create physical impossibilities to demonstrate when and where our perceptual process collapses. During these isolated moments, we can then analyze the paramount elements contributing to our minds' interpretation of a cohesive image and draw a correlation that may be applied to computer graphics.

BIOGRAPHICAL SKETCH

The author was born in China on April 26, 1976 and grew up in New Jersey for most of her life. She has received degrees of B.F.A. in Digital Media and a B.A. in History of Art from Cornell University in 1999. In 1999 she also joined the Program of Computer Graphics at Cornell University as a Masters Student.

For My Mom,

Whose Stubbornness I Inherited

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Introduction

1.1 Challenging the Familiarity of Sight

Our perception of the world around us seems so naturalistic that one would hardly ever question the *truthfulness* of what our eyes present us. As Richard Gregory, Professor Emeritus of Neuropsychology at the University of Bristol, had stated in his opening statement about the psychology of s*eeing*, "We are so familiar with seeing that it takes a leap of imagination to realize that there are problems to be solved [*Gregory* 7]." For a time, we believed that our visual process is faithful to reality, like a camera, reproducing and translating every detail to our mind. Likewise, the world of computer graphics also embraced this idea of *seeing* and recreated a virtual world as a precise replicate of the real one. However, explorations and experiments with perception psychology have offered a new approach in which only objects visually recognized should take priority in the recreation of a scene.

With this intention, we created an installation, the *Impossible Vase.* This installation explores the "problems of seeing" and serves two purposes: 1) as an artistic expression in challenging the viewer's sense of familiarity through visual cues, and 2) as a perceptual documentation on the visual thresholds explored through each of the projected experiments. The installation demonstrates that the viewer's sense of familiarity is governed by the human perception system's visual thresholds. We hope that these discrepancies in the visual system will become an advantage in the presentation and the computation of computer graphic simulations of the real world.

Seeing requires several levels of cognitive awareness that one takes for granted. We naturally familiarize ourselves within our environment through the sense of sight. The attribution of meaning and behavior to an object is automated and sometimes done on a subconscious level. We expect rocks to be hard and pillows to be soft. It would be highly unusual for us to find there were soft rocks and hard pillows. To test how much these preconceived behaviors affect our visual experience, the Impossible Vase takes an ordinary vase painted completely white and re-projects its color attributes onto the white vase. We then changed some aspect of the vase so that it does not behave within its normal parameters. The final result produced an illusion that appeared physically impossible but the illusion was strong enough to challenge any preconceived behavior we expect from an everyday object such as this vase. This investigation into the human visual system and the process of cognitive thinking was equally as intriguing as the effect created by this experiment.

1.2 Thesis Organization

This thesis is organized in the following manner to help explain the perceptual explorations involved with the *Impossible Vase* installation. We start off with Chapter 2, which includes a short re-investigation of perceptual issues and explorations in traditional masterpieces of the western world. This chapter also presents give a brief introduction to some aspects of the human perception system. Chapter 3 subsequently covers some of the current art works and methods influencing the *Impossible Vase* installation. Chapter 4 explains the process of putting together the installation to help the reader understand the way the illusion was created. Chapter 5 analyzes the perceptual issues created by the *Impossible Vase* illusion and gives a comparison analysis to some of the works referenced in Chapter 2. Finally, Chapter 6 offers the conclusion and thoughts of future implications from this project.

Chapter 2

Illusions and Perception in Art:

A Re-investigation of Traditional Masterpieces

2.1 Perception and Art

While Perception and Visual Arts are coexistent in practice, it is difficult to delineate the moment when artists or architects became aware of perception as a biological phenomenon that can be manipulated through organized visual compositions affecting the cognitive process. For example, artists utilize the effects of color relativity where colors may appear different when juxtaposed to lighter / darker or cooler / warmer colors (Figure 2.1). However, did the artist only recognize the visual effects of such application, or did he also understand the biological effects of the cones and rods in his eyes? In architecture, the application of perceptual corrective devices can be traced to as early as the entasis of Greek columns, while artists have incorporated the effects of color relativity and perspective in their works from as early as the 15th Century. Despite the lack of in-depth biological understanding underlying perception, artists in the past were far more aware of the perceptual intricacies governing our cognitive experience than we might expect.

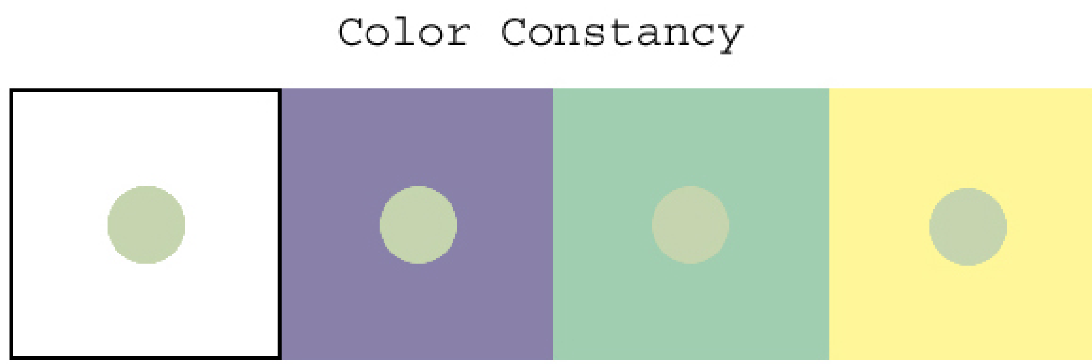

Figure 2.1 Color Constancy Chart
Notice that the green circles may look darker or lighter in comparison to its surrounding color.

With most Perception Psychology studies occurring within the last two centuries, it is hardly surprising that most of the Art works exploring this field occurred relatively within the same time. From the works of French Modernist Pierre Bonnard (1867-1947) to Dutch Illustrator M.C. Escher (1898-1972), explorations of spatial recognition to localized perception are expressed within each master's works. Several artists and their works shall be analyzed in this chapter to demonstrate different aspects of the human perceptual system.

2.2 Perspective

Artists' pursuit to represent three-dimensional objects within two-dimensional depictions has made *depth perception* one of the most explored areas in pictorial representation. Early representations of depth and space often consisted of a diagrammatic language and had little adherence to the way the viewer actually saw things in reality. Some systems used the position on the canvas to relay distance. In Eastern art, for example, objects located on the bottom of the image often represented items that were closer to the viewer; similarly, objects higher on the canvas were farther from the viewer (Figure 2.2). Uniform size and detail were drawn irrespective to the distance of the objects portrayed.

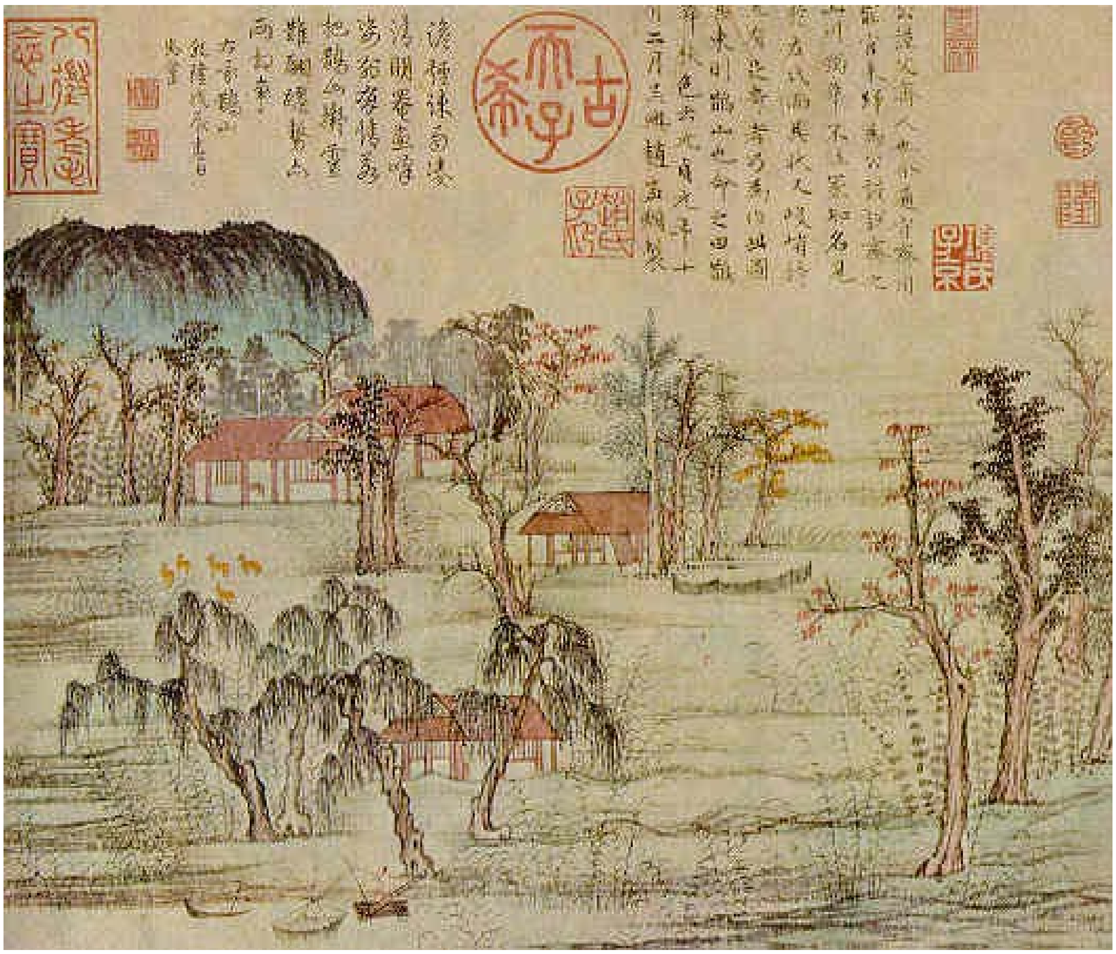

Figure 2.2 Chao Meng-fu, *Autumn Colors on the Ch'iao and Hua Mountains*

Portion of Handscroll, ink and color on paper, Chinese, 1295. This rural landscape was painted by Zhao Meng Fu during the Yuan Dynasty. The houses and trees are drawn with uniform size and rely on their position on the canvas to relay depth. Objects occupying lower portions of the canvas represent things that are closer to the viewer while things farther away from the viewer are portrayed on a higher section of the canvas.

It was not until the Italian Renaissance that a more naturalistic system of depicting pictorial space was developed. The Italian Renaissance was the first period that widely applied perspective to relay depth and distance. Documentation of such concepts can be traced back to Leon Battista Alberti who had created an outline of the laws and principles of perspective demonstrated by Filippo Di Ser Brunelleschi's drawings during the early 15th century. Leonardo Da Vinci's notebooks also conveyed the idea of translating perspective directly "on a plane behind a sheet of glass… of pyramids, and these pyramids are intersected on the glass plane (Gregory 164)." These concepts were commonly later adopted by Dutch illustrators and captured by Dürer's woodcut print in his publication of *Underweysung der Messung mit dem Zirkel und Riichtscheyt,* 1st Ed, 1525 (Figure 2.3).

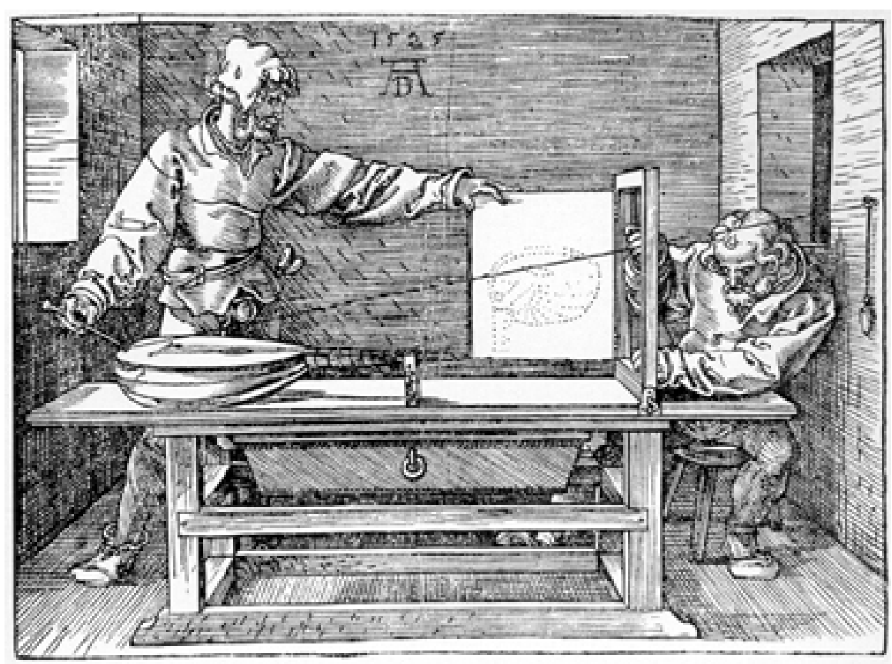

Figure 2.3 Albrecht Dürer, *Tracing a Lute,* Woodcut print**.**

Print from *Underweysung der Messung mit dem Zirkel und Riichtscheyt.* This print demonstrates that a ray can be extended from the object to the viewing plane to create a perspective drawing of a three-dimensional object onto a two-dimensional canvas.

In comparison to the history of civilization, the development of perspective seems rather surprisingly recent. According to Gregory, “It is an extraordinary fact that simple geometrical perspective took so long to develop – far longer than fire or the wheel – and yet in a sense it has always been present for the seeing (Gregory, 164).” Perspective is perhaps the only aspect of spatial representation that predates modern studies of perception psychology.[1] In this respect, the late development of perspective may not be so unusual relative to the speed in which we are learning about our perceptual system.

[1] Modern studies of perception psychology refer to the cognitive studies of the human visual system. This does not include the biological studies of the human eye, which can be traced further back.

2.3 Size Constancy

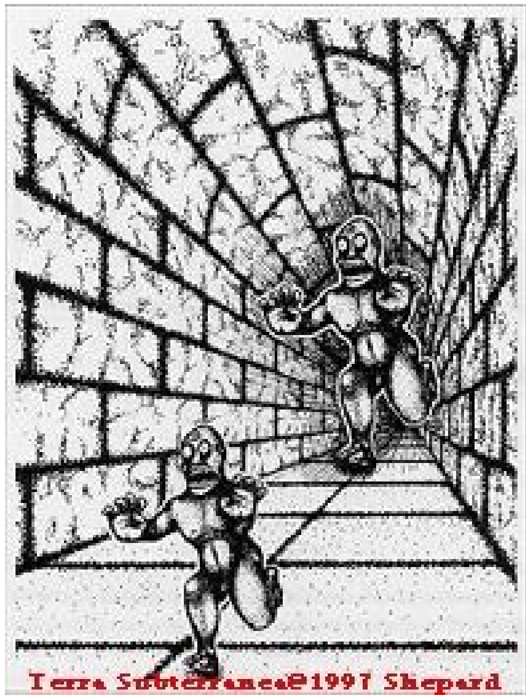

Figure 2.4 Size Constancy illustration.

This illustration was conceived by Stanford psychologist Roger Shepard demonstrating size constancy. The two figures in this illustration are drawn the same size, but the viewer interprets the figure on the right to be larger. The viewer's understanding of size is related to the distance at which the object is perceived. Since the figure to the right looks farther away, it therefore must be larger than the one to the left in comparison.

Size constancy is the interpretation of depth and distance by our visual system through the comparison of two objects of known or comparable size. In the illustration by Stanford psychologist Roger Shepard, even though the two figures are the same size in the illustration, our visual system automatically assumes that the figure on the right is farther away and larger in size (Figure 2.4).

Figure 2.5 Photo of two figures standing in Ames Room.

The Ames room provides the viewer with conflicting visual information that override's the visual system's size constancy comparisons. The two figures look largely disproportionate when standing on the opposite corners of the room. Photo from <http://www.exploratorium.edu>.

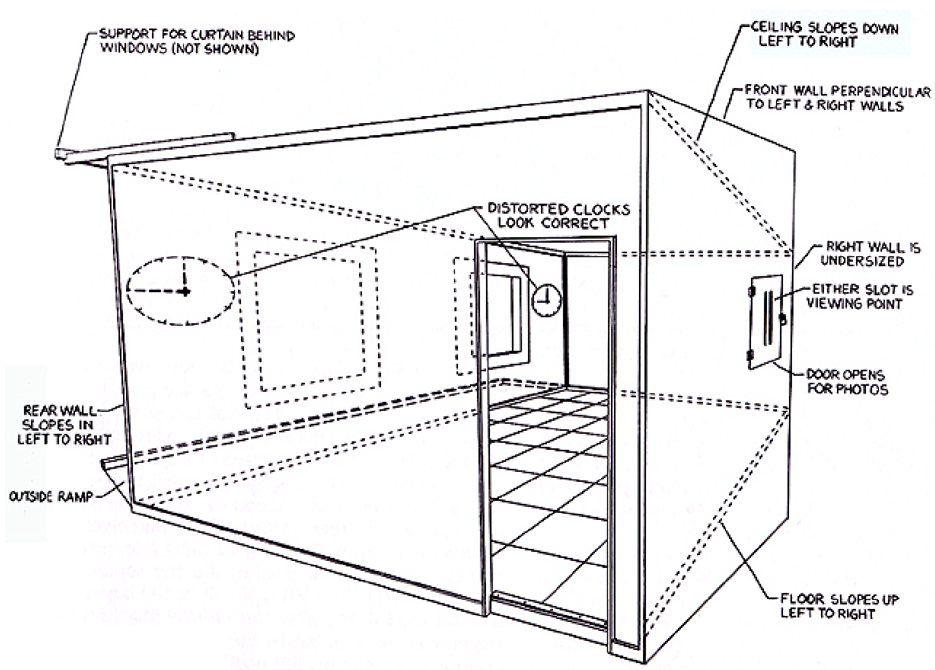

Figure 2.6 Diagram of the Ames Room (Bruman).

This diagram shows the proportions of the room are not rectilinear as perceived from the viewing point. The Ames Room uses the unlikelihood of an extremely distorted room to convince the viewers that the figures in the room are disproportionate rather than the room itself.

Ames room, (Figure 2.5) has been widely known to provide our visual system with conflicting information and override our visual system's size constancy comparisons. The reason this illusion works is because the point of view is restricted to a specific spot. All the visual cues of Ames Room lead the eye to believe that the room is a perfectly rectilinear shape (Figure 2.6). With conflicting visual signals, the viewer's mind is tricked into believing that the people standing within the room are largely disproportionate in size to everything else. Ames room "brings out the point that perceptual interpretation involves on betting on the odds. The extreme distortion of a room is so unlikely… that perception goes wrong when the truth is unlikely (Gregory 180)." Edward Hopper's painting *Second Story Sunlight, 1960* also relies on size constancy to convey depth (Figure 2.7). According to Gregory, "Any perspective projection is ambiguous – correct perspective may be a necessary but is never a sufficient condition for indicating depth (Gregory 168)."

Figure 2.7 Edward Hopper, *Second Story Sunlight*, 1960.

Edward Hopper uses visual cues such as shading and size to convey depth in his paintings. The perspective projections in this painting, however, are not entirely accurate.

Figure 2.8 ***Second Story Sunlight*** diagram of areas where the correct perspective projections are not adhered.

This oil painting demonstrates that artists do not always adhere to the correct perspective projections in their paintings. The edges on the roof are parallel while the balcony edge is entirely straight even as it turns towards the side of the house. The only visual cue that the viewer has of the balcony having a side face is through its shading.

Gregory concludes that “If the artist ignores perspective altogether, his painting or drawing will look flat, unless indeed he can utilise other cues to distance with sufficient force (176).” Proving such devices effective, Edward Hopper has demonstrated that in some cases, even without a correct geometric perspective projection, depth can be communicated through other visual cues such as shading and size relativity. In *Second Story Sunlight*, we can see that all the edges of the buildings are parallel from the top edge of the roof to the bottom edge of the roof whereas a correct perspective would contain converging lines (Figure 2.8). The window frames also appear like perfect rectangles. The only indication of depth is from the diminishing size of the windows and the rooftops and the shading of the walls.

2.4 Resolution/Frequency

The term *resolution* nowadays is often associated with computer screens and digital output; however, resolution is an important aspect of visual perception as well. Resolution is a term used to gauge our visual acuity, or resolving power how well our visual system can coherently interpret the level of detail or spatial frequency in which information is visually presented. This characteristic is harder to measure because resolution is dependent on the distance the object is from the viewer. For example, a white picket fence from far away looks like nothing more than a white horizontal line, but as we get closer, we see that it is actually a group of short vertical lines aligned together in a horizontal fashion. Similarly, forests from far away look like a patch of green but in reality is a group of trees placed in close proximity to each other.

For this reason, the metric used is scientifically expressed as cycles / degree (Palmer 20).

Impressionists have often used visual resolution in their works as a commentary to the human memory's impression of scenes. For the most part, the human memory rarely remembers exact details of complex scenes; perhaps this is the reason for our difficulty in recreating portraits from memory. Bits and pieces of information are stored to create an entire image, but the information is only comprehensible when the entire composition is there. Retrieving each piece of information separately will result in an incomprehensible visual form. Impressionists use this aspect of visual psychology to emphasize a certain theme or romanticize the scenes portrayed without distracting their viewers with unnecessary details.

One of the most commonly used art works to demonstrate resolution is Georges Seurat's *A Sunday Afternoon on the Island of Jatte* (Figure 2.9). If the viewer looks at this painting up close, he will see that the painting is nothing more than small blotches of paint strokes. No concrete forms can be distinguished. However from the distance of a few feet, the viewer spatially integrates neighboring samples together and begins to interpret these integrated colors as recognizable forms. Seurat has expertly used visual resolution as a way of captivating his viewer at a certain distance and guarantees that the painting will be remembered as a whole scene. There are no detailed distractions for the viewer such as the detail of a woman's face or the fur of the dog. What the viewer ends up taking away with him is the overall impression of a hazy Sunday afternoon scene. The human visual system is actually quite selective in the attention given to a scene or an area of a scene. Besides resolution, the viewer's attention can be also be directed by creating visual stimuli that draw attention between his foveal and peripheral vision.

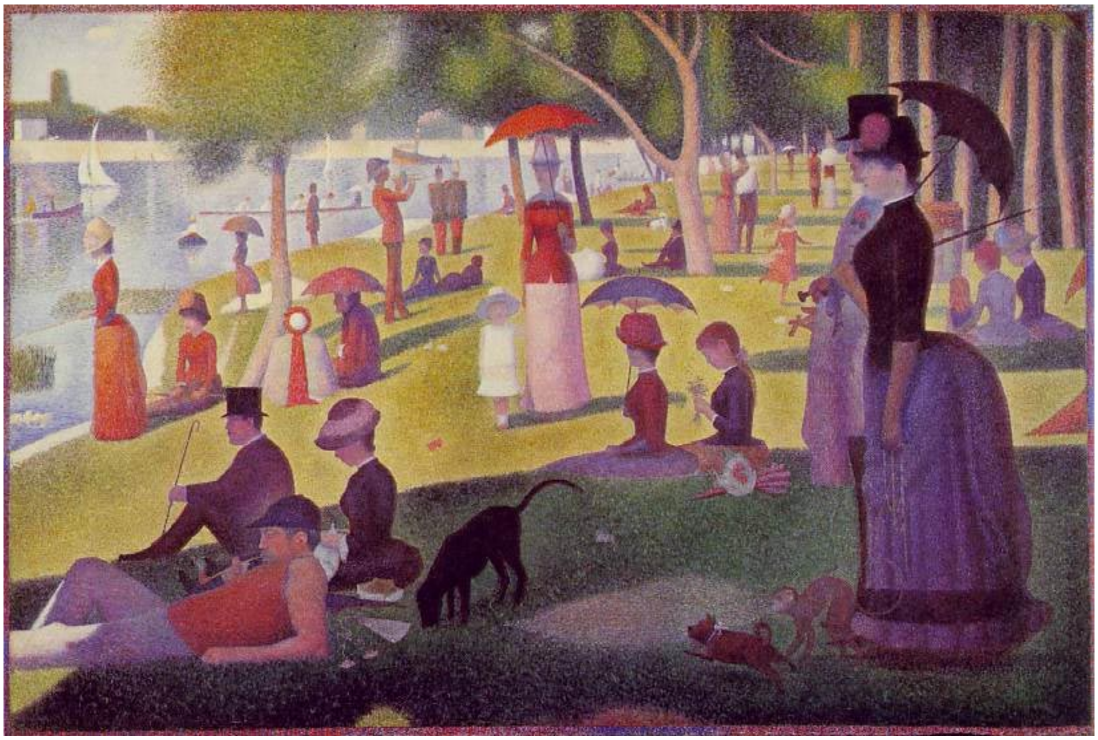

Figure 2.9 Georges Seurat, *Sunday Afternoon on the Island of La Grande Jatte,* 1884-6.

The pointillists' way of painting takes advantage of the human visual acuity to integrate similar patterns into a coherent scene from a distance. Seurat's painting is conceived through small painted strokes in which the viewer integrates similar colors into recognizable patterns and shapes.

2.5 Foveal / Peripheral Visual Acuity

Have you ever seen something at the corner of your eye but when you turned your head to look at the object, you found it to be something entirely different than what you had expected? This is an example of the different levels of sensitivity between your peripheral and foveal vision, which can sometimes create conflicting signals for your mind to interpret. The peripheral vision is much more sensitive to motion and light contrast levels while the center of your eye is much more sensitive to spatial and color vision (Palmer 29-31, 466). Because of the difference in sensitivity, artists have often used these thresholds between your peripheral and foveal vision to create new textural effects. While standing up, if you look down and hold out your hand so that both your feet and your hand are in the same view, you will find it difficult to simultaneously see both your hand and your feet clearly. This is because the visual angle covered by the fovea is only two degrees, which is roughly the size of your thumbnail at an arm's length (Palmer 31).

French modernist, Piérre Bonnard uses the human visual system's behavior to bring new meaning into his works. He not only captures the subject he paints in a certain manner but he also captures the way the viewer should see the subject. John Elderfield has noted in his essay that "a painting by Bonnard might be usefully thought of not as representation of substance but as a representation of the perception of substance (Elderfield 33)."

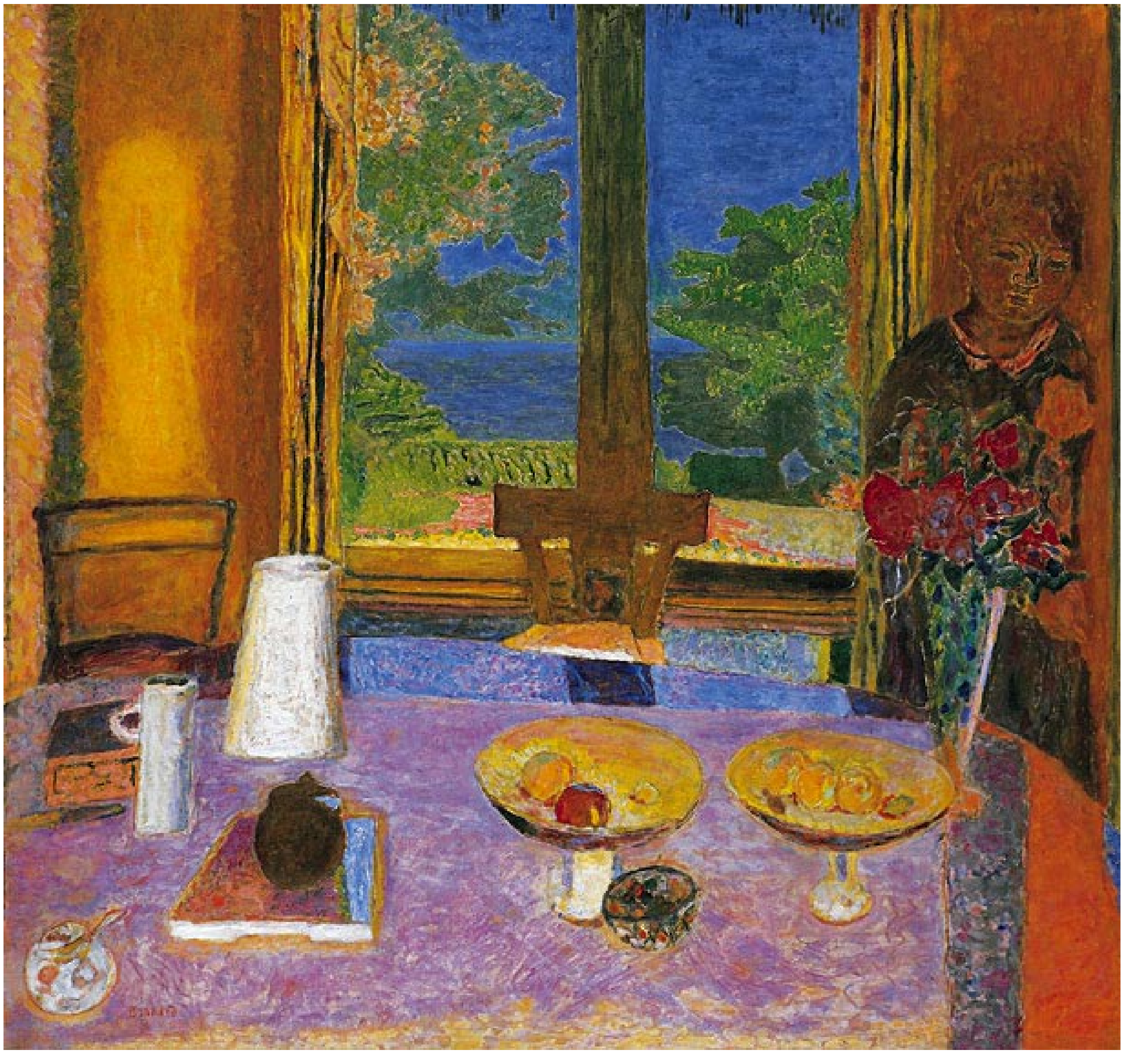

Figure 2.10 Piérre Bonnard, *Large Dining Room Overlooking the Garden*, 1934-5.

In this painting, Bonnard uses the visual thresholds between the peripheral and foveal vision to guide the viewer's perception of the subject. The latent acknowledgment of the female figure at the far right is brought forth by the contrast sensitivity of the viewer's peripheral vision. The same technique is evident in many of Bonnard's other paintings, such as *The Open Window* (1921) and *The Red Cupboard* (1939).

In *Large Dining Room Overlooking the Garden*, 1934-5 (Figure 2.10), Bonnard uses the viewer's sensitivity to contrast along his peripheral vision to create a latent acknowledgment of the female portrait of Marthé. When the viewer initially sees *Large Dining Room*, he first focuses on the central region of the painting, as most viewers are accustomed to viewing any framed representation.[2] Bonnard reinforces the central attraction by using brighter colors in this area and darker colors that are lower in contrast around the edges of the painting. This application of colors shows an understanding of the human visual system in which the foveal region has a higher sensitivity to colors and spatial recognition while the peripheral vision is sensitive to contrast (Palmer 29-31). In this painting, the lower contrasted figure standing along the edge of the painting will inevitably attract viewer's attention even if it is not noticed initially. When the viewer then glances toward the edge, he becomes aware of the standing figure, which was a moment ago beckoning attention along his peripheral vision.

From the introduction of Seurat's *A Sunday Afternoon* and Bonnard's *Large Dining Room*, we begin to realize that our level of visual understanding occurs at two levels. One level of understanding occurs at the local level where details are gathered. This level often occurs during the saccadic movement of our eyes as they roam around an image or environment. The areas that we focus on become stored as local visual information. The second level of understanding is at a higher cognitive level in which the detailed pieces of information are combined to form an overall comprehension of our surrounding.

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[2] The framed representation is like a window view in which the edge of the painting represents the borders of the window. David Hockney refers to this as the "keyhole" view.

2.6 Localized Perception

Local perception can be defined as seeing an object in parts whereas global perception is the seeing of the entire image at once. When you enter an office space, global perception will allow you to recognize that you are within an office while local perception will allow you to take in the details such as the desk, the chairs, and the whiteboards. The widely debated issue of whether local visual processing or global visual processing predominates the overall perceptual experience has often intrigued both perception psychologists and artists alike. Sometimes the local information can interfere with the global perception. Artists have often used such interferences to create impossible illusions with their work.

Dutch Illustrator, M.C. Escher, (1898-1972), has many times captivated his viewers with impossible illusions in his prints. His later works such as *Belvedere* (1958) and *Ascending and Descending* (1960) in particular have utilized the confusion of the viewer to interpreting local and global visual information to create physically impossible scenes (Figure 2.11). Whereas Ames room relies on the viewer's willingness to believe that a familiar object such as the room cannot be anything but normal, Escher's works relies on the viewer's unwillingness to believe a familiar object can behave in an unorthodox manner.

In *Ascending and Descending*, the viewer understands that the stairs cannot possibly be going up or down infinitely in a loop, but when the viewer traces the steps, each section appears to make sense locally. However, a higher level of thinking convinces the viewer that there is no possible physical reference in the real world that resembles the illustration of the scene.

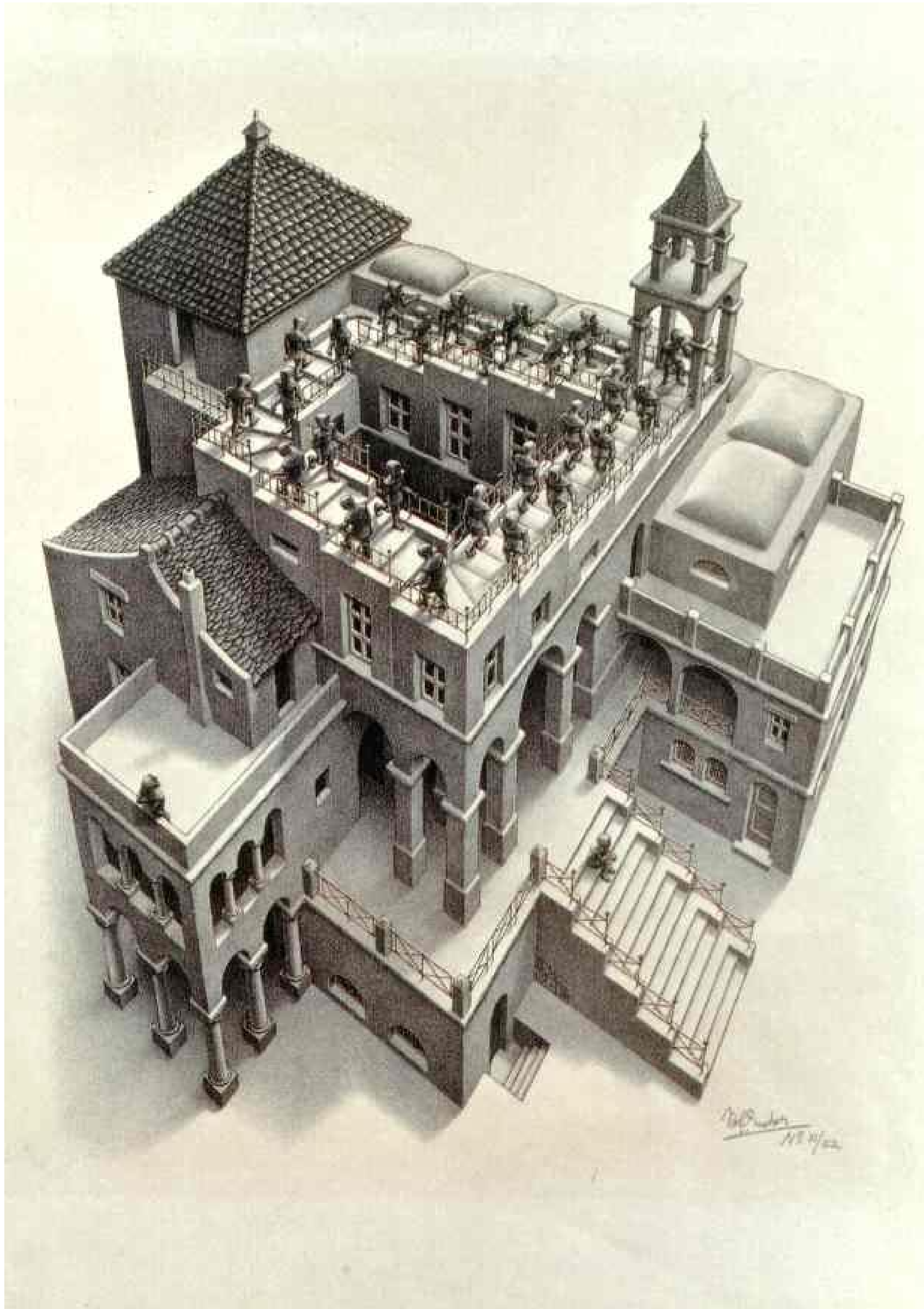

Figure 2.11 M.C. Escher, *Ascending and Descending*, Lithograph, 1960**.**

Escher's *Ascending and Descending* creates an impossible illusion of unending staircases. The staircases present conflicting information for the viewer's local and global perception system creating a cyclical process of investigation and attempts to formulate a conclusive understanding of the image.

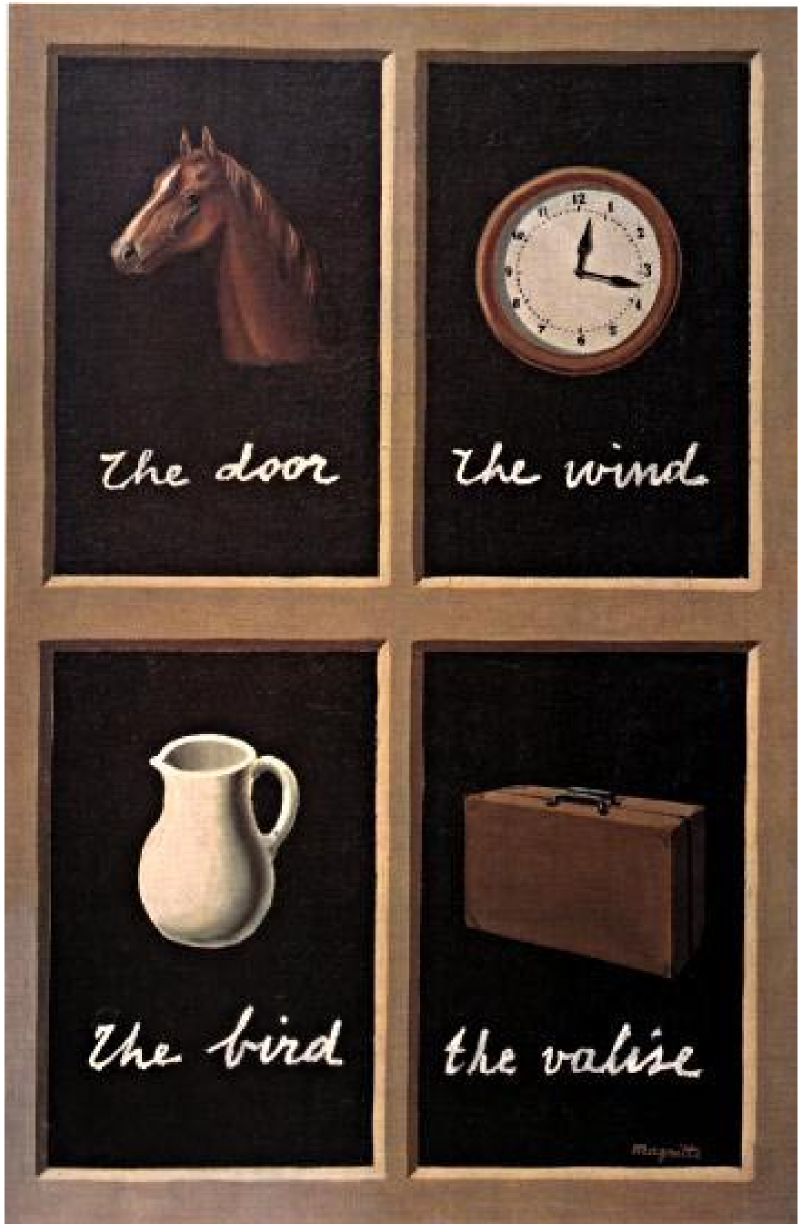

Figure 2.12 René Magritte, *Key of Dreams,* 1930.

This painting demonstrates the disjunction between seeing and understanding. The label attributed to each image is not conventional to the name we have been accustomed to associating with each object.

The disjunction in *Ascending and Descending* appears to have derived from the higher cognitive level in which the local visual information is pieced together to create the global interpretation. During this process, the viewer's understanding of the world is being challenged with what he sees. A similar example is seen in René Magritte's (1898-1967) *Key of Dreams*, 1930 (Figure 2.12). This painting demonstrates how our visual system functions on two levels: one is to react on the immediate visual information received by surveying the environment, and another is to react on a preconceived understanding about the world around us. In *Ascending and Descending,* the information provided by these two levels conflict with one another creating a cyclical process of investigation and attempts to formulate a conclusive understanding of the image. In John Berger's *Ways of Seeing*, he notes:

> Seeing comes before words. … It is seeing which establishes our place in the surrounding world; we explain that world with words, but words can never undo the fact that we are surrounded by it. The relation between what we see and what we know is never settled. … [Berger, 7]

Our understanding of the world through visual communication is constantly tested and redefined by new visual stimuli. Sometimes, even the familiar aspects of seeing should be tested in order for us to gain a greater understanding of the way we see. In the following section, Pop artist David Hockney re-examines the construction of the one point perspective by creating a new way of seeing through the "reverse" perspective.

2.7 The Reverse Perspective

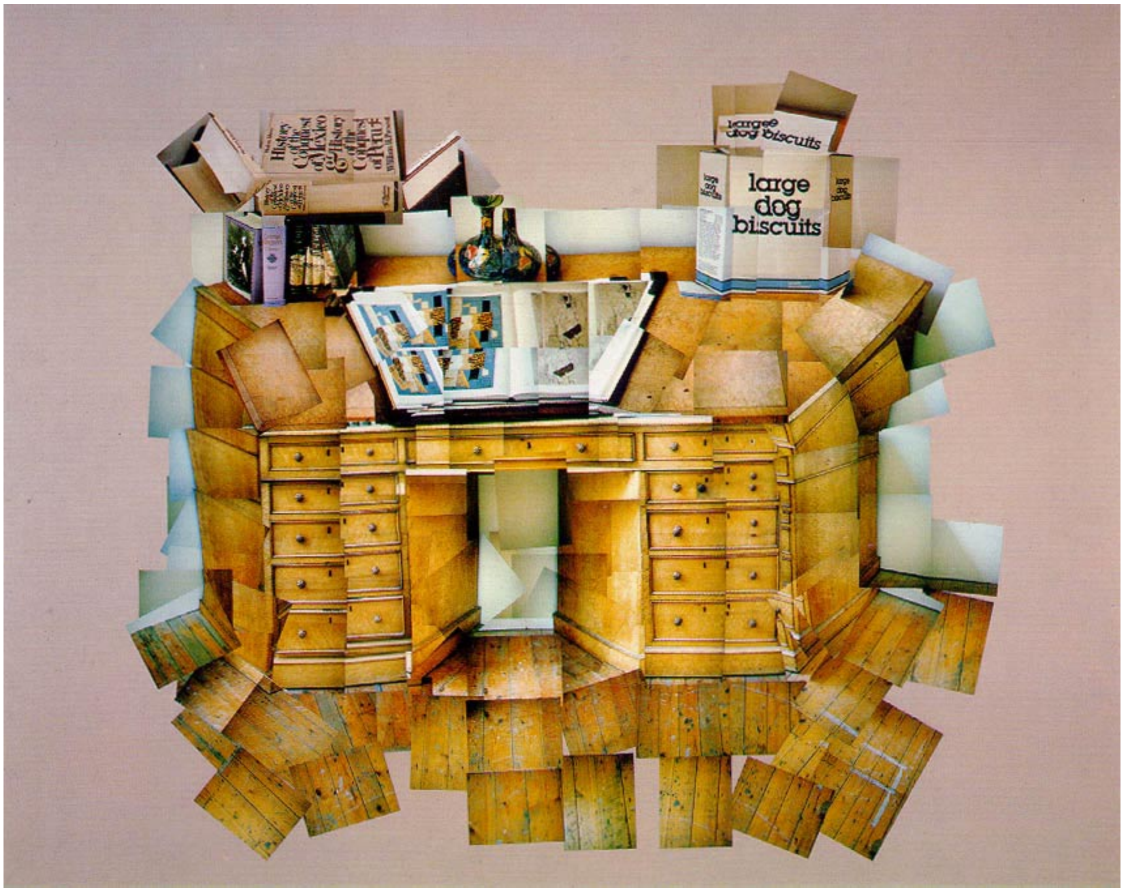

Figure 2.13 David Hockney, *The Desk*, 1984

Hockney refers to his photo collages, such as *The Desk,* as images with a *reverse perspective* because his compositions create parallel projections that converge at the eye of the viewer and project out towards the world. Regular perspective drawings, however, have parallel lines that converge at infinity and project towards the image plane.

David Hockney has often referred to his photo collages as art representations of a reverse perspective. In a correct geometric perspective, objects converge into one or more vanishing points; in Hockney's collages, objects diverged rather than converge from the viewer's vantage point. Hockney's earlier application of the reverse perspective can be seen in his 1984 photo collage, *The Desk* (Figure 2.13). The viewer can recognize the subject as a desk and also understand the artist's physical position in relation to the desk while taking the photo. From this, we can see the influence of cubism in Hockney's works; the viewer has the ability to move around to the object and see from the artist's point of view.

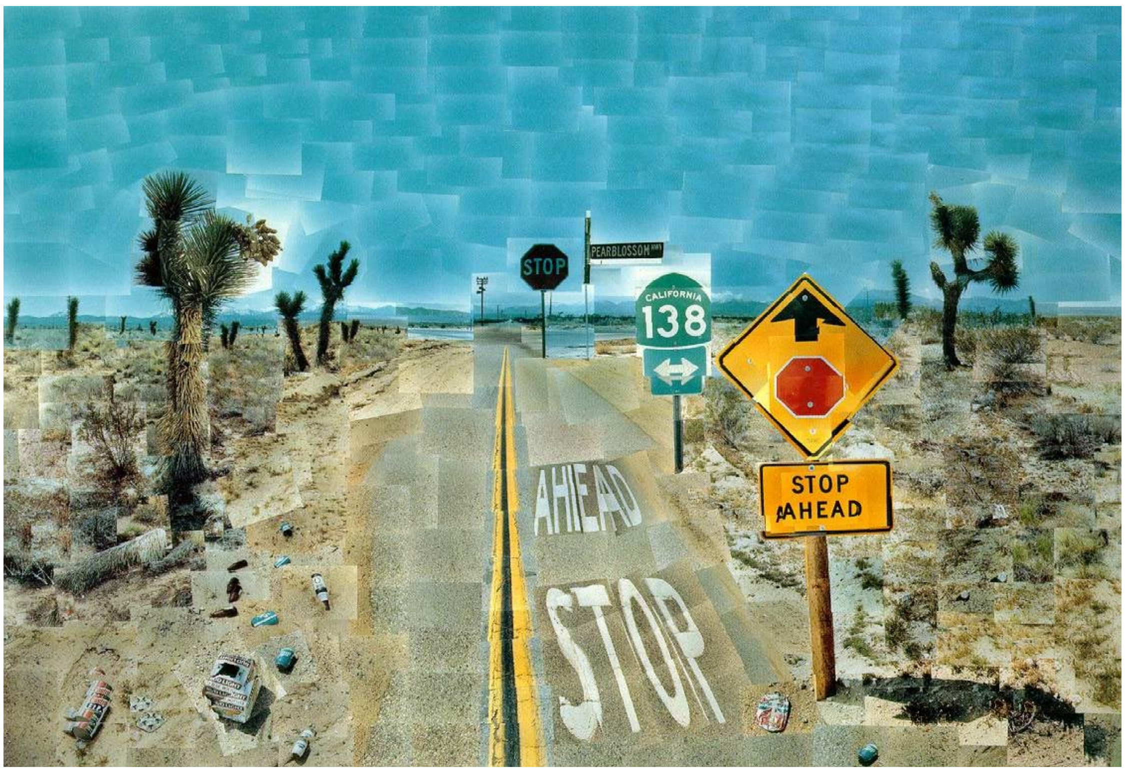

Figure 2.14 David Hockney, *Pearblossom Highway*, April 11-18th, 1986

Each photograph in this collage presents a different perspective and composition. The edges of the photographs do not align with each other but the viewer still manages to interpret this collage as one composition.

However, in his later photo collage, *Pearblossom Highway* (Figure 2.14), we can see that the composition has gone from a diverged perspective to one resembling the correct perspective. The most unusual aspect of this collage is the local information provided by each photograph while the mind interprets the entire collage as one composition. Each photograph has its own perspective and composition from the point of view taken by the camera. The edges from one photograph to the next do not even align with its neighbors, yet when the viewer looks at the entire collage, the information somehow makes sense. Hockney comments that:

> …there are different ways of depicting space; one way is a keyhole way, essentially the window idea, the one-point perspective. The window is just a big keyhole with edges around it. And you begin to realize that it is the edges that define the keyhole…. (Hockney 103)
>
> I see [Pearblossom Highway] as a panoramic assault on Renaissance one-point perspective. (Hockney 112)

Hockney's exploration in spatial vision is very similar to that of Cubist painters like Pablo Picasso. Cubist paintings not only explore spatial vision but also spatial occupation of the subject through time. This aspect of portrayal is captured in the form we know as "motion."

2.8 Motion

While most art works we have discussed thus far explore spatial vision, many artists have also created works exploring the human visual system's understanding of time. Viewers can experience time through visual manipulations often captured in cinematic works in which time expresses a change in space. In such works, time and space are inseparable entities. Only through a change of spatial occupation can the viewer sense the passage of time. For example, can the viewer sense the passage of time if we created a videotape of objects that did not move? What if we then took a still photo of the same scene? We know that the photo only captures one specific moment in time. But if there is no difference between the videotaped scene and the still photo, can the viewer understand that there is any passage of time?

Conceptual artist, Marcel Duchamp captured the sense of motion by portraying subsequent spatial occupation in *Nude Descending a Staircase, No. 2* (Figure 2.15). By combining several separate moments into one piece, he has created a narrative. Of course, this narrative only makes sense from our preconceived understanding of how a figure would move when descending a staircase.

As John Berger had pointed out, "the way we see things is affected by what we know or what we believe (7)." In all art works, the ideas and moments captured by each piece are always part of the past. Events occurring in the past often relies on the human memory for comprehension. In *Nude Descending a Staircase, No. 2*, the viewer is invoked to call upon his own memories of seeing someone, at one time or another, descending a staircase. In our memories, the event is categorized as one action, "descending." From this painting, it appears as if Duchamp has captured a memory rather than simply documenting an event.

Cubism also used combined perspectives to transcend one single moment in time. The viewer is able to see several points of view simultaneously, but the information is more comprehensive as a narrative. In cubist paintings, not only is the subject portrayed as occupying different spaces, but the viewer also occupies different spaces in the painting through the prompting of the artist.

Figure 2.15 Marcel Duchamp, *Nude Descending a Staircase, No. 2*, 1912.

Duchamp's *Nude Descending a Staircase, No. 2* captures the sense of motion by portraying subsequent spatial occupations through overlapping images of the figure descending the stairs. This painting depicts the human visual system's visual short-term memory, which allows the viewer to understand motion as a narrative (Palmer 580).

Figure 2.16 Pablo Picasso, *Femme Couchée*, 1932. Oil on canvas

Picasso's *Femme Couchée*, like many cubist paintings, portrays his subject in multiple perspectives. There is a combination of movement in time and space in which the viewer appears to occupy different vantage points while the sleeping nude shifts in position as well.

In Picasso's *Femme Couchée*, 1932 (Figure 2.16), there is combination of movement in time and in space. The viewer can see the sleeping nude turning at different moments but the viewer is also moving around the sleeping nude. The perspective of each position of the nude figure slightly shifts simultaneously with the angle of the viewer. This painting becomes a three dimensional narrative captured on a two dimensional surface. Through this narrative, the viewer develops a rapport with the subject as well as the space the artist occupies. This understanding becomes the beginning of the process we know as perception.

2.9 Perception issues represented in Art

Perception goes beyond simply seeing; it is a combination of seeing and understanding the world around us. Perception in art is often based on the viewer rather than subject. It is how the viewer sees the subject that is most interesting in these representations. For this reason, art has become a great empirical documentation of the human visual system. Whether it is with or without the understanding of the biological function of our eyes, art has produced a prolific journal into the way we see.

Chapter 3

Previous Works

3.1 Perceptual Influences from Entertainment

Creating an immersive synthetic environment that emulates reality has long been a challenge to the computer graphics industry. For decades, computer graphics researchers and developers have attempted to simulate the real world. Several endeavors in fields like military or pilot training, entertainment, and the digital arts have been successful. Virtual reality laboratories, such as the CAVE environments, provide a surround-screen, surround-sound, and projection-based system so the viewer's visual and aural senses are entirely immersed in the simulation. With the advancements of new technologies such as 3D printing, the possibility of reversing the process and bring simulated realities into the real world has become a new venue to explore. Projected environments have taken their first steps of bringing the intangible graphics of the computer screen into the real world we live in.

Intuitively, the idea of a synthetic environment produced through projected imagery is nothing more than an extension of a projected film onto a three-dimensional surface rather than the two-dimensional canvas of a movie screen. However, as simplistic as this statement may be, the difficulties of creating a convincing synthetic environment arise from the sensitivities of the human visual system. The illusions fall apart when the environment does not behave similarly to the one that we already understand. Examining the previous works in this field, we find that controlling the visual experience interactively has been realized by deconstructing the physical properties from its perceptual properties such as color.[3] Perhaps in future media, there may be interactive physical screens that may change shape physically, but currently our projects have been limited to static surfaces.

Some of the earliest experiments with perceptual illusions and digital projections can be found in Disney's Haunted Mansion. The Haunted Mansion has two rooms, in particular, which take advantage of the intricacies of the human perceptual system to create special effects. The first room is the *Stretching Room* in which the room appears to elongate vertically as the viewers stand in it.

The *Stretching Room* was originally built as part of Disneyland's (California) entrance to the Haunted Mansion. The original design for the Haunted Mansion, in 1963, had made it a walk-through attraction, but was later modified in 1967 to become a ride. As a ride, it was decided that all the effects could not be incorporated into the one building of the Haunted Mansion. Since the building of the Haunted Mansion had already been built, the designers decided to dig a basement level and have it tunnel outside to the rest of the attraction. The *Stretching Room* thus became a method of transportation to a lower level. When Walt Disney World (Orlando) was built a few years later, the *Stretching Room* became so popular that it was kept as part of the Haunted Mansion, even though there was no longer a need to

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[3] While the wavelength of light reflected from an object is a physical property, the interpretation of color is entirely a perceptual phenomenon. The mind's interpretation of the wavelength of light cannot alter the wavelength in any shape or form (Palmer 95)

Figure 3.1 Disney's Haunted Mansion, *The Stretching Room* (HMIP)

The Stretching Room is covered with vertical-striped wallpaper, which removes any vertical visual registration and helps give it the illusion of stretching.

create a basement level. The new Haunted Mansion adapted the *Stretching Room* to have the ceiling and wall move up rather than having the elevator drop (HMIP).

The success of the *Stretching Room* is due to its wallpapering of vertical stripes (Figure 3.1). The vertical striping removes any registration visually of where the elongating motion begins. Notice that the room can elongate in two possible ways. One possibility is for the ceiling or floor to retract revealing more vertical area of the room or the room can stretch like a rubber band. Of course the latter situation is not physically plausible. The removal of any visual cues on the vertical surfaces allows the room to appear as if it is "stretching" during the retraction of the floor or ceiling. Although the Stretching Room is not a projection illusion, similar illusions of motion can be applied to projective technology.

The showcase of Disney's Haunted Mansion, *The Grand Ballroom* is another example. In *The Grand Ballroom*, viewers pass a staged area in which ghostly figures dance around the ballroom mysteriously disappearing and reappearing. The holographic illusion of the ghostly dancers is produced by reflections rather than the widely accepted misconception of the dancers being holograms.[4] This effect is similar to a stage illusion that was invented in the 18th century by Sir John Henry Pepper, a professor of chemistry at the London Polytechnic Institute. Pepper's ghost is illustrated in Figure 3.2 and explained in plan view in Figure 3.3.

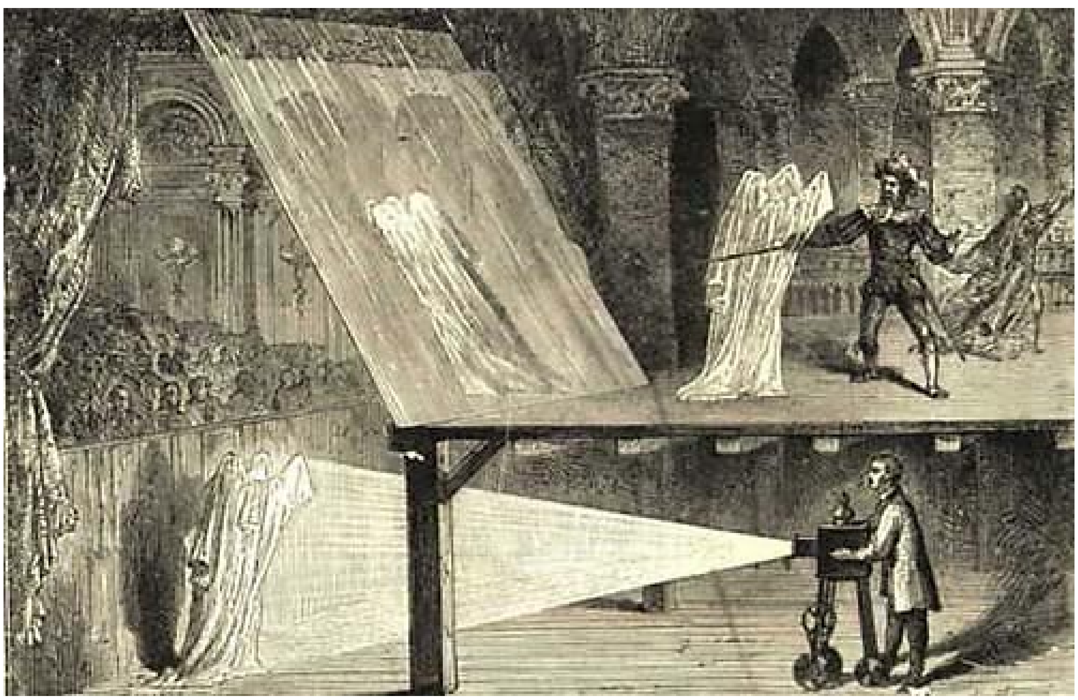

Figure 3.2 Illustration of the Pepper's Ghost illusion in *Ghostmasters* (Walker).

Pepper's ghost is produced through the reflection of a nearby figure hidden from view onto a glass plane. This illusion is much like looking out a window at night with the interior lights on. The viewer can see through the window but will see a reflection of the interior as well.

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[4] Holograms are, by definition, three-dimensional illustrations made with a laser.

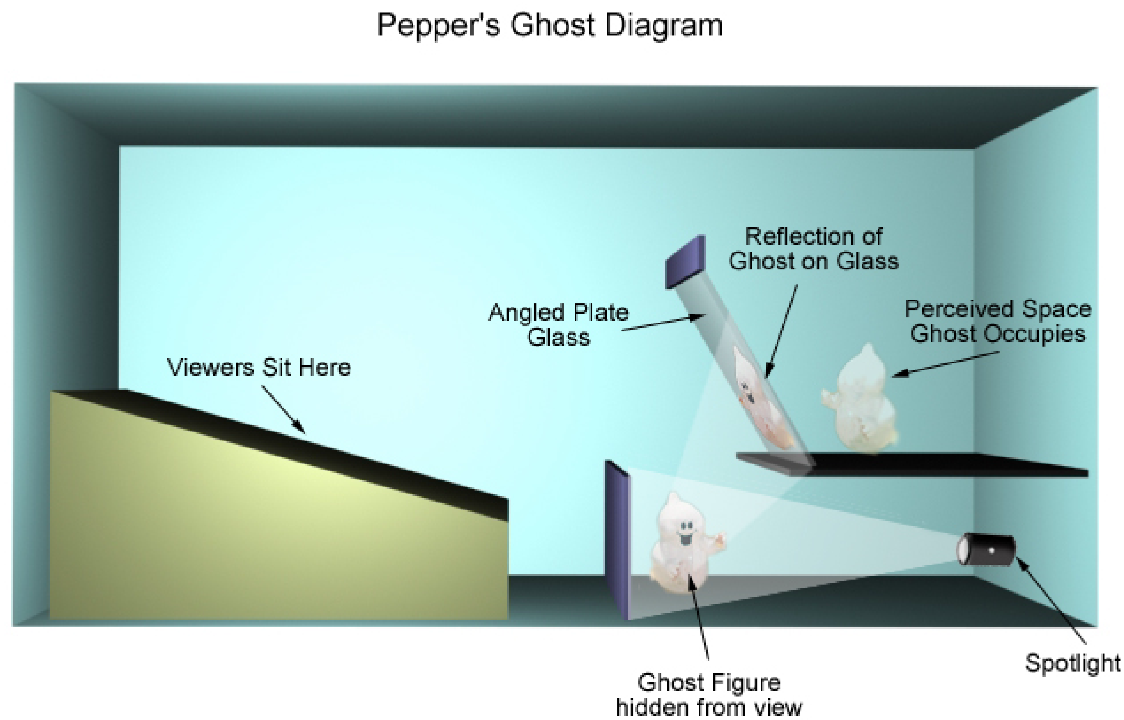

Figure 3.3 Plan of Pepper's Ghost.

The angled plate glass on stage reflects the hidden figure of the ghost. The level of transparency of the reflection can be controlled by the intensity of the spotlight shone on the hidden figure. As long as the placement of the glass and figure is consistent with the stage scene, the viewers perceive the reflection to occupy the same space as the rest of the stage set.

The ghost image that the audience sees is a reflection of the actor on the lower left corner of the diagram. The reflection is seen on the piece of glass placed in front of the stage. Disney's Haunted Mansion has placed the ghost animatronics beneath the actual trail, which is juxtaposed to the ballroom but hidden from the viewers (Figure 3.4).

The coloring of the ghost dancers and organist however is entirely created through lighting. The mannequins for the animatronics are primarily white with very light coloring (Figure 3.5). The final effect that the audience sees is the accumulation of color light projections on white animatronics reflected on glass (Mayhem).

Figure 3.4 Stage set for the *Grand Ballroom* in Disney's Haunted Mansion

The actual animatronics for the ghost dancers are hidden beneath the tour trail, which can be seen in the left of the photo (Mayhem). Using the concept of Pepper's ghost, the animatronics are reflected by a clear glass plane (not seen in photo) into the actual ballroom seen on the right.

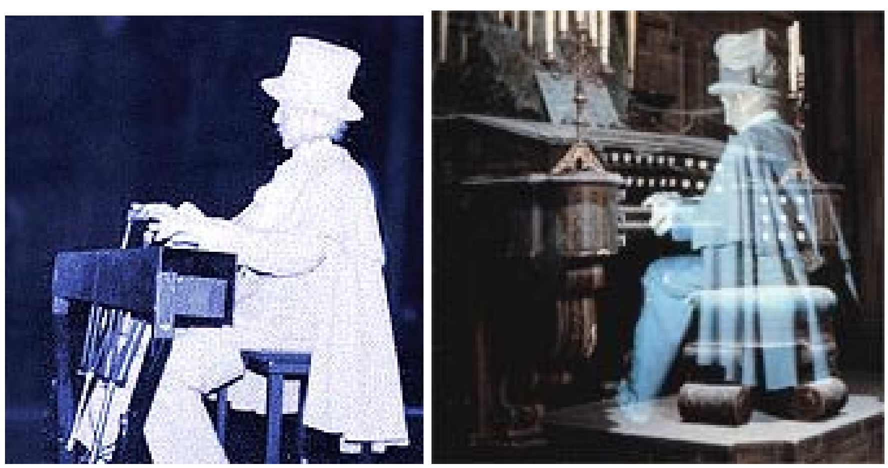

Figure 3.5 Organist animatronic for Disney's Haunted Mansion.

Left: The animatronic for the ghost organist is actually white and hidden from view. Its motions are synchronized with the keys of a real organ positioned on the opposite side of the room (Mayhem). **Right**: A glass plane, placed between the viewer and the organ reflects the image of the organist with projected colors creating the ghostly effect. Photo from <http://www.epinions.com/trvl-attract-Walt_Disney_World-Magic_Kingdom-Liberty_Square-The_Haunted_Mansion>.

3.2 Influences from Art

Michael Naimark created a series of projects exploring digital projections in art and telecommunications. In the 1984 installation, *Displacements,* Naimark had filmed two live actors within a living room with a 16mm camera on a rotating turntable. After filming, he spray painted the entire room white and used a film projector to cast the film back onto the room itself. The projected areas of the room had looked convincingly realistic except for the areas the live actors occupied (Figure 3.6). This experiment had the greatest influence on our installation, which is presented in the next chapter.

The *Displacements* installation made a distinction between the reality of the physical world and the perceived reality of the virtual environment. The physical objects are still there, but the objects have been stripped of their perceptually descriptive nature in color and perceived texture. For example, the chair is now simply a chair. It's no longer a *red leather* chair until the film projector casts its virtual counterpart on top of it. Naimark had once said:

> If you want a mediated experience to look and sound (and feel and smell) real, go to the motion picture industry….If you want an interactive mediated experience, go to the computer world. But since it is younger and less evolved than the world of cinema, it has addressed interactivity more in the context of here-and-now practicalities than in the context of future sensory-rich virtual realities, where theoretical factors such as simultaneity, memory, and interruptability become essential. [Naimark 2]

That was eleven years ago; more recently, computer graphics has also brought in more "realness[5]" in the look and feel of interactive applications.

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[5] Term adapted from Michael Naimark's essay titled *The Art of Human Computer Interface Design.* "Realness and Interactivity."

Figure 3.6 Michael Naimark, *Displacements*, 1984.
Top: Still capture of a live actor in living room taken from the 16mm camera. **Middle:** Living room is spray-painted white after filming. **Bottom:** Photo of the re-projected living room including the live actor from the top image.

For this installation, Michael Naimark used a 16mm camera placed on a rotating turntable to film a movie of the room. The re-projection of the movie onto the white room creates a convincing likeness of the original except for the areas previously occupied by the actor. The projection of the actor as a texture creates a disjunction between the viewer's understanding of the room and its correlating color/texture properties.

3.3 Educational/Research Influences

In 1998, Marc Levoy at Stanford University created several tests on changing material properties through light projections. Using a gray *Happy Buddha* model, he scanned the geometry and then used two projectors with different color ranges to project the different textures back onto the model. The simulation of the textures was achieved by varying different colors and intensities of the projections from the side and the front. Although these tests have not yet been published in a paper, he has included his research on his web site (Levoy) with the following results (Figure 3.7).

Figure 3.7 Stanford's *Happy Buddha* (Levoy).

The simulation of the textures was achieved by varying different colors and intensities of the projections from the side and the front. **Left:** The Stanford *Happy Buddha w*ith uniform color and illumination from both the side and front projections. **Right:** Same statue illuminated with a different colored projection from the side. The illumination simulates an antique look not inherent in the original object.

In 2001, Raskar et al. from the University of North Carolina Chapel Hill and MERL introduced *Shader Lamps,* a new method of using multiple projectors to graphically illuminate physical objects with textures and BRDF simulations. The objects are scanned using a 3D touch probe sensor and then textured with material properties simulating appropriate perceptual appearances based on the position of the viewer. In the following scene, Raskar et al. have used a Taj Mahal Model to demonstrate the complexity of the detail provided by the *Shader Lamps* method (Figure 3.8)

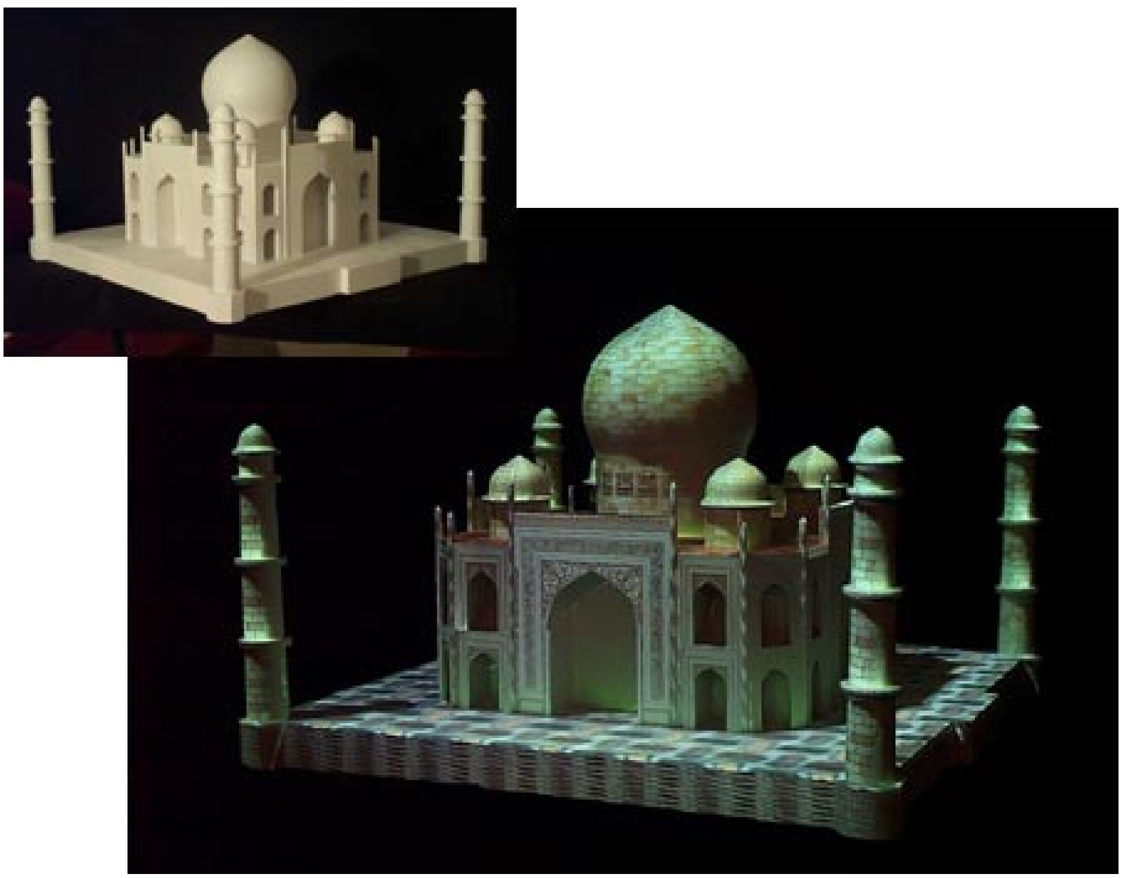


Figure 3.8 Model of Taj Mahal illuminated using *Shader Lamps.*

Raskar et al. from the University of North Carolina Chapel Hill and MERL introduced *Shader Lamps* as a new method of using multiple projections to graphically illuminate physical objects with textures and BRDF based on the position of the viewer.

Although an immersive virtual environment has been a long sought-after goal and promise of the computer industry, “the combination of realness with interactivity is a new frontier where experienced pioneers today are [still] few, and come from such diverse worlds as flight simulation, dream research, and experimental theater” (Naimark 1). It is our hope that the combined influence of the technological advances in the computer industry and the investigation of digital art and perception psychology will help make this a realization.

Chapter 4

Installation of the *Impossible Vase*

4.1 The Digital Sculpture

media, -ums – *n .pl form of medium.* A means of expression as determined by the materials or creative method involved**.**

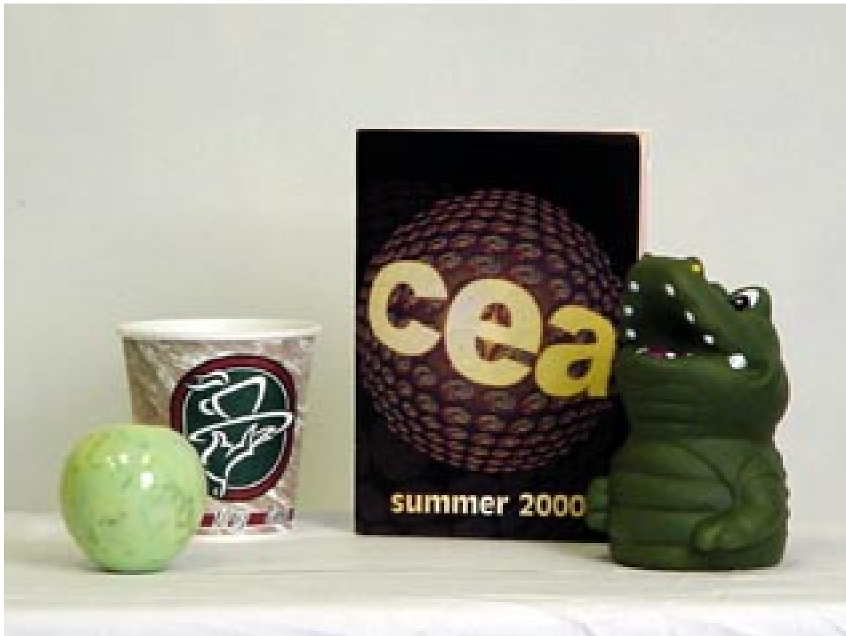
sculpture – *n.* The art or practice of shaping figures or designs in the round or in relief, as by chiseling marble, modeling clay, or casting in metal.

movie – *n.* [Shortening and alteration of moving picture] A sequence of photographs projected onto a screen with sufficient rapidity as to create the illusion of motion and continuity.

- American Heritage Dictionary

The duality of the *Impossible Vase* being both sculpture-like and movie-like provides us with issues on the classification of its medium. Despite its familiar analogues to cinematic media, it has been created more as a digital sculpture than a movie. It is our hope that the viewers see the *Impossible Vase* in this light. This chapter will provide a detailed description on the making of the installation and the environment required to create a convincing illusion. Although the documentation of its making may have the viewer believe it to be a cinematic endeavor, it is more important to see the installation as a whole and deconstruct its perceptual effects rather than a general deconstruction of its intrinsic media.

4.2 First Run



(a)

(b)

Figure 4.1 Captures of Test Scene 1.

(a) Original objects. **(b)** Projections onto objects.

The *Impossible Vase* was first an attempt to realize digital projections into the physical world and create digital sculptures by utilizing solid canvases. Each object in the physical world had a virtual counterpart whose projection completed its appearance with color and texture details. A few test scenes were created to address the human visual system's response to a 3D projected sculpture. Despite the viewers' surrounding in low ambient light, the perceived digital sculpture will be created by an area of concentrated light projection. This contradictory state left us uncertain to the response of the human visual system.

In the first test scene (Figure 4.1), we tested small and simple objects to see which type of objects would yield interesting results in this experiment. Digital photographs of the objects were taken before we spray-painted them white.[6] These photographs were then re-projected onto the objects by a LCD projector, the *JVC DLA-G10U*, from the position that the original photographs were taken.

[6] The final creation would use rendered scenes of scanned 3D models, but to keep the testing phase simple and immediate, digital photographs were used instead.

Figure 4.2: Close up of test scene with booklet.

From the first test scene, we were able to make some speculations to the conditions in which the human visual system would be forgiving under low lighting. From Figure 4.2, the detailed image projected onto a simple flat object, like a booklet, appeared to be too washed out. This effect was most probably a limitation to the brightness and contrast of the projector or a function of the distance of the projector to the objects (see Layout below for details). The first test scene also appeared monochromatic due to a lack of red and blue textures. The surprising aspect of the first test scene was that the complexity of the model, such as the toy alligator, did not seem to deter the projection from creating a realistic impression. A subsequent test scene was then constructed.

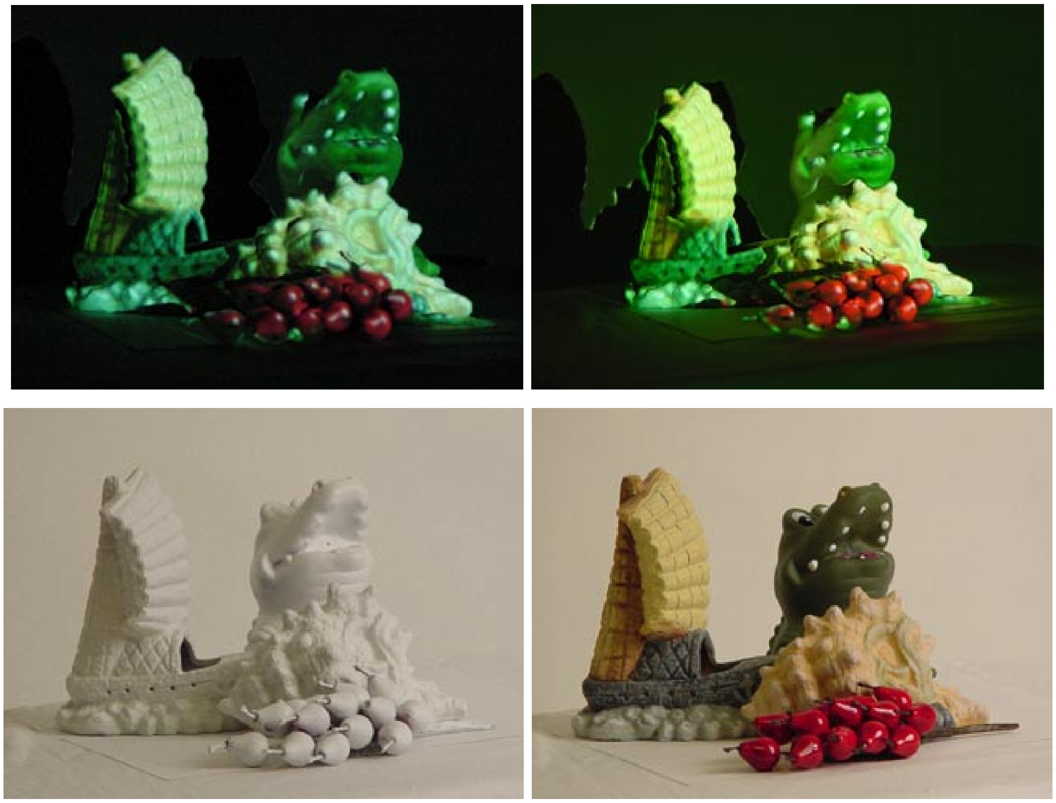


Figure 4.3 Comparison photographs from Test Scene 2

Top left: Projection of Test Scene 2. **Top right:** Projection of saturated digital photograph. **Bottom left:** Objects painted with matte white paint. **Bottom right:** Original objects.

The second test scene added new items that provided more contrast in texture, color, and shape. The porcelain sailboat and seashell provided matte surfaces while the red berries tested gloss. The objects also varied from the seashell's bumpy surface and angular contour to the alligator's smooth round surface. In the second test scene, we also saturated the colors of one of the projected photographs to test if we could create an illuminated effect (Figure 4.3).

From the two test scenes, several possibilities became apparent. The complexity of the objects was not a problem as originally feared. The projection of the textures onto a matte finished surface did not prevent the illusion of specular or illuminated surfaces.

4.3 The Idea

Our initial test scenes suggested it was possible to create a digital sculpture with texture changing properties. Since many concurrent research projects were testing synthetic projected textures, the idea of combining an organic looking object with synthetic textured items became our target goal. Until this point in time, only hard surfaces such as metals and ivory were being tested.[7] The idea of including a non-trivial organic object such as a still life of a floral arrangement started to look like a good challenge. A turntable was also added to provide the capability for generating a dynamic sculpture.

Figure 4.4 Flowers and vase with turntable base

[7] Mark Levoy's project made the Buddha statue look antique while Raskar et al. at University of North Carolina created textures for the Taj Mahal.

The arrangement seen in Figure 4.4 was assembled from objects easily obtainable from any crafts store with the exception of the turntable, which was made from a rotating Christmas tree base coupled with a marble stool top. The original material of the vase is glass while the flowers are made out of cloth. Only one flower remained in the final installation to simplify the task.

Figure 4.5 Scanning the 3D model of the flower

The vase and flower were first scanned[8] using the MicroScribe Digitizer to create an accurate 3D model (Figure 4.5). Each 3D model preserves their physical counterpart's size and shape. The models were then brought into 3D Studio Max[9] to be completed with the texture of our choice (Figure 4.6). The original glass vase and cloth flower were then painted with white paint and placed back onto the turntable. A light trap made from black velvet cloth was placed behind the sculpture to keep any alignment issues from distracting the viewer (Figure 4.7 and Figure 4.8).

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[8] The use of the word *scanning* implies the procedures used to acquire the three-dimensional geometry of the objects used in the scene.

[9] 3D Studio Max is a modeling and animation software created by Discreet, a division of AutoDesk, Inc.

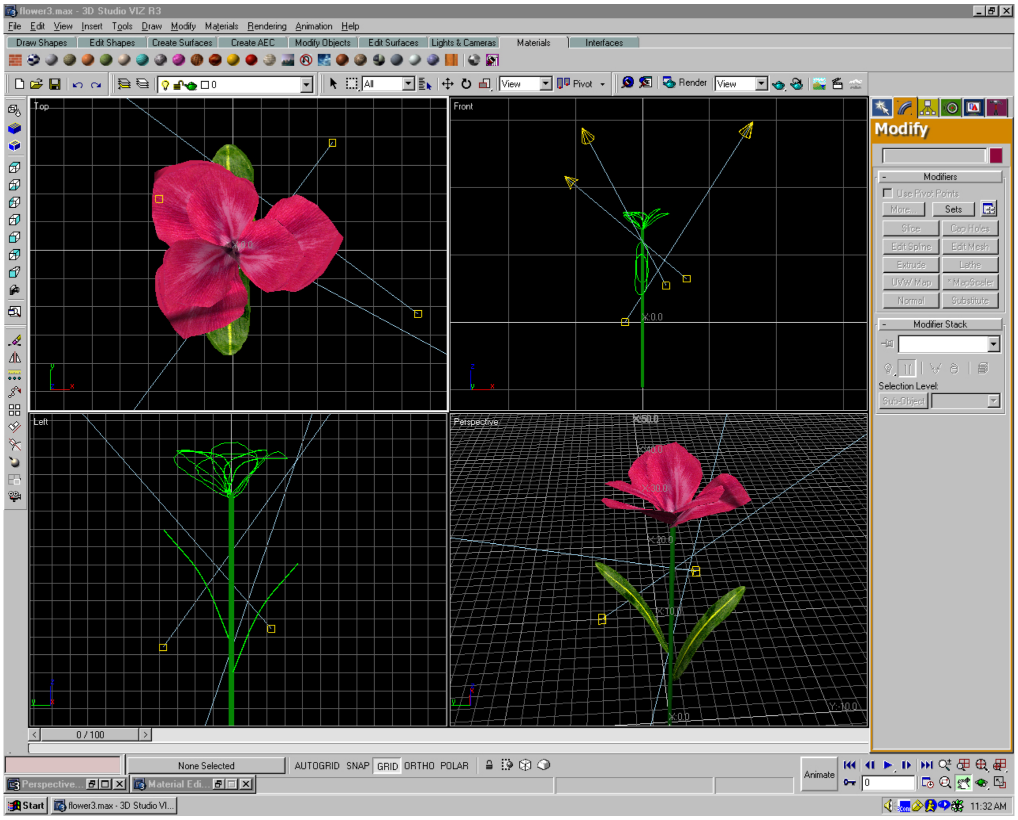


Figure 4.6 Screenshot of digitized model of flower from 3D Studio Max.

Figure 4.7 Full set of the *Impossible Vase* without projection.

Figure 4.8 Photo of projections with light trap.
Left: Photo of projected virtual textures on flower and vase. **Middle:** Overexposed photo showing entire projected area on light trap. This cannot be detected by the human eye. **Right:** Detail of projected textures.

4.4 Layout

Because *The Impossible Vase* required an environment with controlled lighting to maximize the effects of the projected images, we have adapted an outdoor tent of 9ft x 12ft x 6ft in one of our offices (Figure 4.9). The tent has a two-layer covering of felt with flaps near the entryway that may be lifted to create a viewing area (Figure 4.10). The viewing area for this particular installation needed to be controlled since the illusion of *the Impossible Vase* is partially view dependent.

The adapted tent creates a low light environment with the vase and turntable placed on the opposite end of the tent from the entrance. The projector was placed slightly below eye level near the entrance as a compromise between the projector becoming a viewing obstruction and creating a projection faithful to the viewpoint of the spectators' position. The distance of the projector from the vase is approximate 8.5 ft. Figure 4.9 also shows the tent environment replicated in a virtual simulation in 3D Studio Max. A virtual camera is placed where the projector stands within the 3D model and renders the final projected movie.

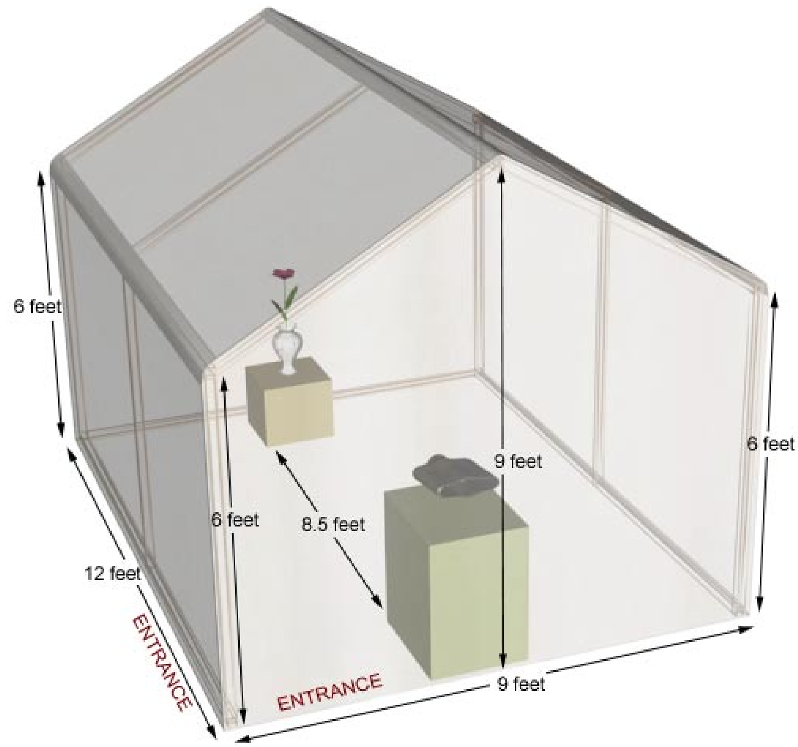


Figure 4.9 Diagram and dimensions of the tent and installation.
The dimensions of the tent is 9ft x 12ft x 6ft. The projector is placed slightly below eye level and approximately 8.5 feet away from the vase.

Figure 4.10 Photo of installation within tent.
The tent provided an environment with controlled lighting to maximize the effects of the projected images

4.5 Changing Material Properties

Once the models were scanned and brought into 3D Studio Max, we began to test the possibility of changing the material properties of the installation completely. The first scene was put together to emulate the original properties of the floral arrangement as a reference point for future adaptations (Figure 4.11). Aside from simply applying new textures to the virtual models, we wanted to alter the opacity of the physical model through the projected images as well. The test results are shown in Figure 4.12 and Figure 4.13.

Figure 4.11 Vase with original opaque texture projections.

Figure 4.12 Vase simulating an iridescent texture similar to Tiffany's favrile glass. The simulation was created with raised glossiness and transparency

Figure 4.13 Vase simulating transparent glass and bumpy surface.

The iridescent vase shown in Figure 4.12 was created by increasing the glossiness of the vase's material in 3D Studio Max, which in this picture captures the reflection of the virtual lights. No real lights were included in this simulation because their inclusion might cause a double specular effect. The bumpy glass vase (Figure 4.13) was created in a similar fashion in which a bump map was added and the transparency of the material was raised to allow the viewers to see the stem of the flower. Unfortunately, the alignment of the stem is view-dependent and created curved distortions on the real vase when the viewer did not stand directly in front of the vase.

4.6 The Illusion

When the first installation of the *Impossible Vase* was assembled, our goal was to test the way human perception recognized material properties through lighting effects. An animation of the flower and vase turning was created in 3D Studio Max to synchronize with the turning of the real turntable. During one of our trial runs, the turntable was accidentally left turning while the virtual animation had stopped. This simulation created an astonishing effect of the vase being incongruous despite our logical mind telling us the implausibility of the lip and flower turning while its base remained stationary. At this point our experiment expanded from investigating the perception of convincing visual effects to the cognition of visual narratives, where the effects of time and memory in digital simulations play a key role.

Chapter 5

The *Impossible Vase*'s Investigation in Perception

5.1 The Eye of the Beholder

> Legend has it that a gentleman once approached Picasso and criticized that Picasso's paintings distorted reality. Appearing to change the subject, Picasso asked the gentleman if he had a picture of his girlfriend in his wallet. The gentleman produced her picture upon such prompting, whereupon Picasso said, "She's beautiful, but she's so tiny."

The *Impossible Vase* was produced as a digital art installation investigating the sensitivity of the visual thresholds in the human perceptual system. Although the final product appears as one cohesive illusion, the effect is produced through several combined triggers of the human perceptual system. In this chapter, we shall retrace some of the topics covered in chapter two in relation to the *Impossible Vase* installation.

5.2 Localized Perception

When a viewer looks at an Escher print, the effect is almost instantaneous, yet his mind ponders at the incredulity of the image. In what way has the betrayal of his eyes deceived his mind? Visual perception does not rely on the basis of what is real, but rather on what is *perceived* to be real. With the visual angle of our foveal perception being only two degrees, reality does not have to be coherent beyond this region. In Escher's *Belvedere* (Figure 5.1), the viewer has trouble distinguishing between the columns in the foreground and background because only the local visual information is consistent.

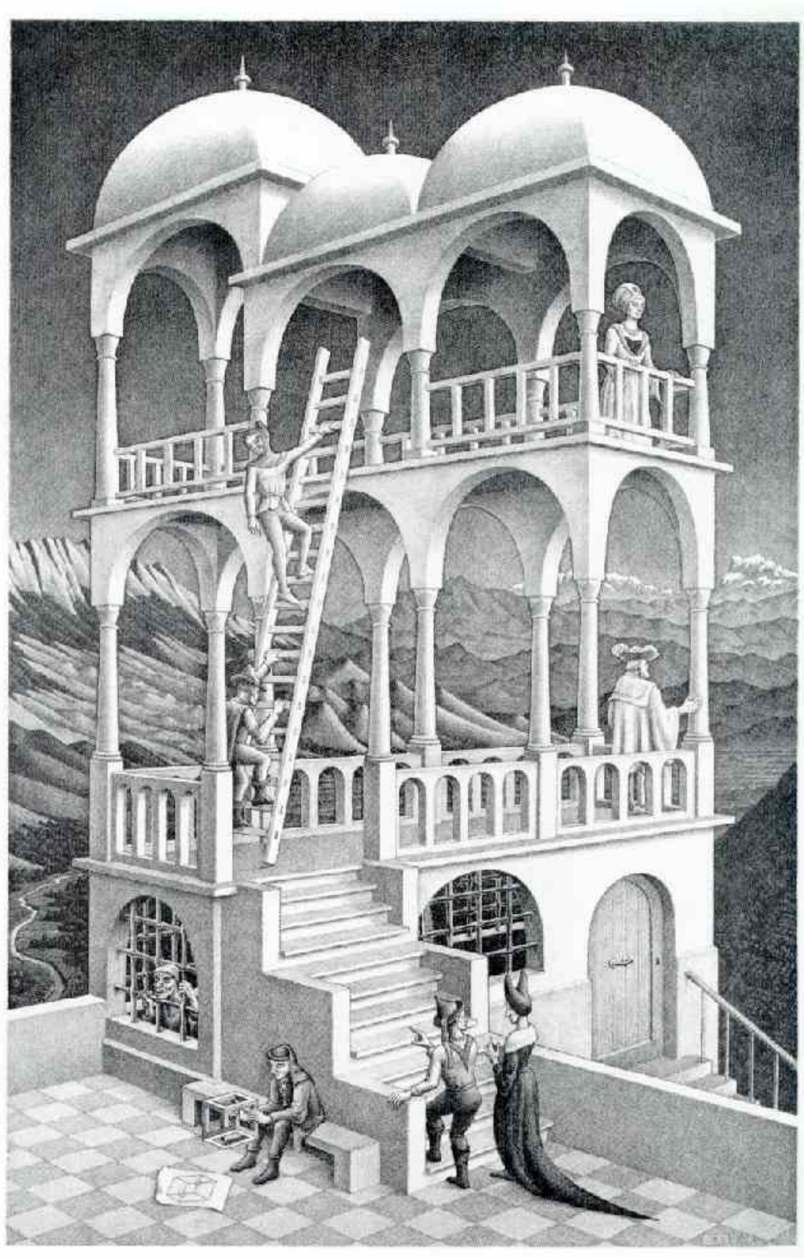


Figure 5.1 M.C. Escher, *Belvedere,* 1958.

M.C. Escher illustrates impossible illusions in many of his prints. In *Belvedere,* the viewer has difficulties distinguishing between the columns in the foreground and background because only the local information in this print is consistent.

The *Impossible Vase* utilizes the same concept by presuming that the visual system initially only registers information locally. By dividing the vase's motion into three sections, each section appears to move in its own direction, yet there is no contortion of the vase's physical body from the motion (Figure 5.2). The visual cues for the vase's motion are sufficiently far apart to keep the local visual information consistent but create discontinuities in the general perception of the vase (Figure 5.3). The visual angle of the fovea, however, only segments the experience of observing the vase in motion. To realize that there's an inconsistency with the visual information that the viewer receives requires a higher level of cognitive thinking.

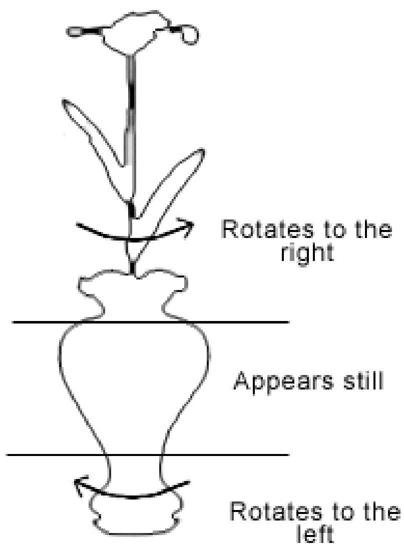


Figure 5.2 Diagram of the vase's rotating motion.

The vase's motion is divided into three sections. Each section appears to move in its own direction, yet there is no contortion of the vase's body.

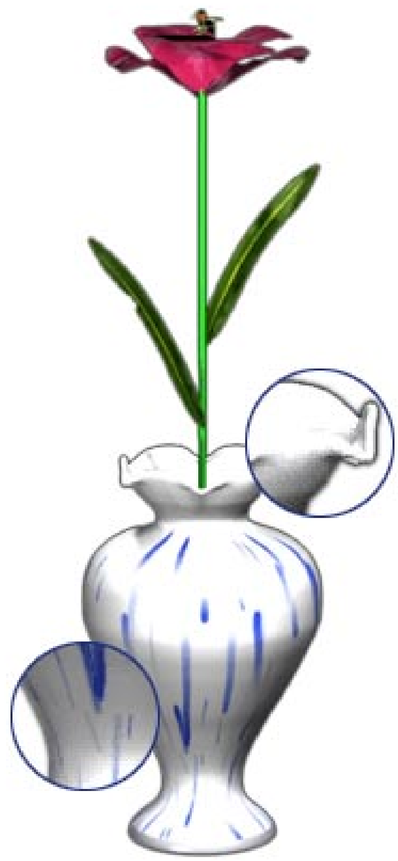


Figure 5.3 Diagram of areas with inconsistent moving parts on the vase.

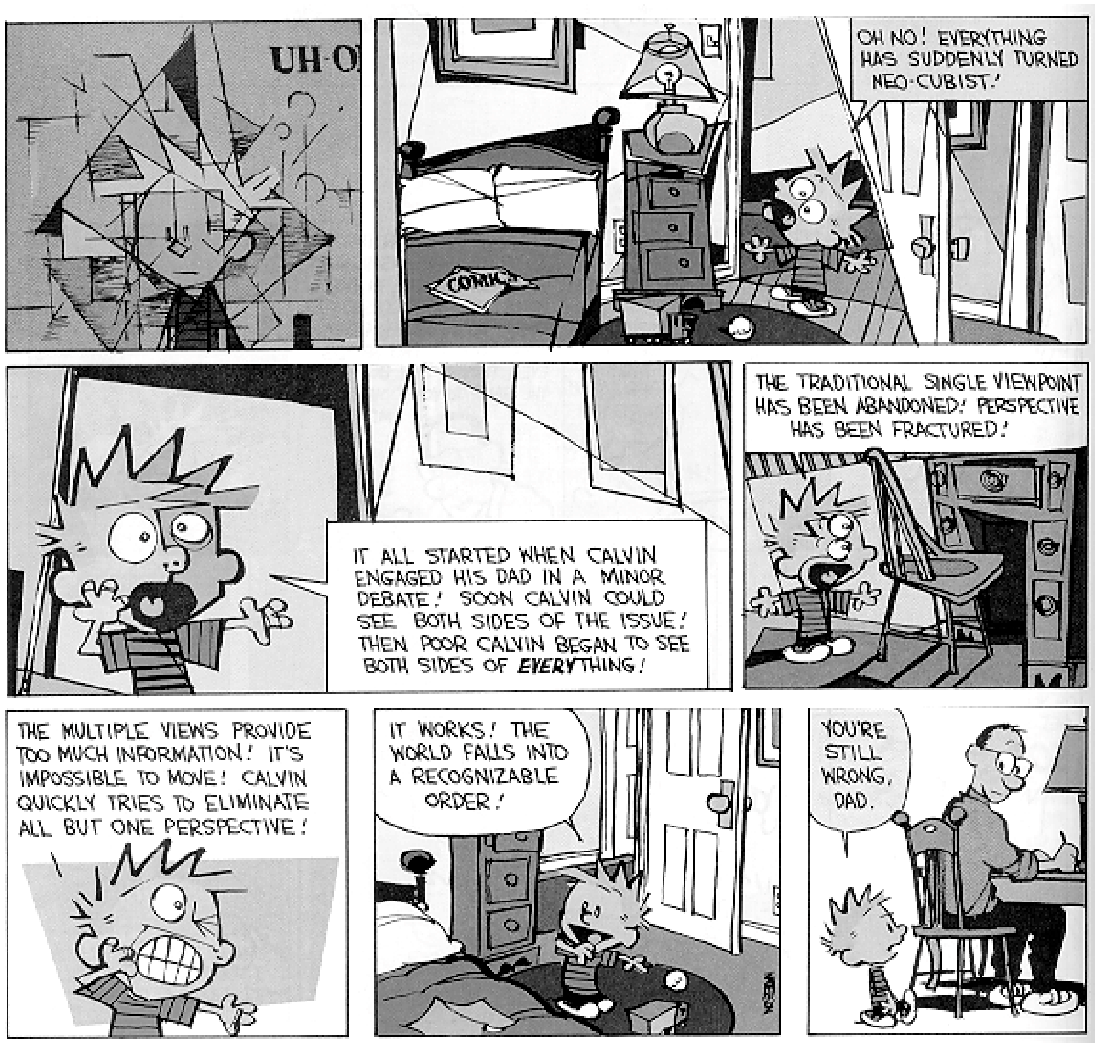
The visual cues for the vase's motion are sufficiently far apart to keep the local visual information consistent but create discontinuities in the general perception of the vase

5.3 Mind in the Gutter

When you look at something…anything, the visual imagery is almost instantaneous and recognition of this visual information follows shortly afterwards. This gap of time in which cognition takes place may be no more than a millisecond, but it is this gap that becomes the most essential part of perception. In art, this gap not only exists to enhance the experience, but sometimes it can be the subject of the artwork itself. In Pierre Bonnard's

Dining Room on the Garden, (Figure 2.10) for example, the moment in which the viewer recognizes Marthé becomes so paramount that this moment of recognition becomes the subject of his painting. Bonnard, in this case, has exercised complete control over the gap in which recognition takes place by subduing the color contrast of Marthé and her background. Most viewers who see the painting for the first time will need time for their eyes to adjust to the lower contrast, therefore delaying his or her recognition of the whole scene.

In other illustrative art works, this gap for interpretation also exists as well. In comic strips, this gap is called the *gutter.* The gutter is the space between the two panels in which the key actions take place (Figure 5.4). Our mind is called upon to create a correlation between the two scenes. The visual information that we receive and our mind's ability to interpret this information becomes a constant dialogue. Sometimes our mind fills in the information that is missing from view. This is done in many different ways. Two in particular should be mentioned here: one way is to fill in the transition from one image to the next, like the area the gutter occupies in comic strips; the second is to *complete* the view in areas that are blocked by the framing of the panel.



gutter

Figure 5.4 *Calvin and Hobbes* by Bill Watterson.

In this comic strip, the viewer adds closure to visual elements providing limited information. He or she automatically creates a correlation between two scenes and bridges the gap left between the frames of the panels. This gap is also known as the *gutter*.

According to Scott McCloud, the author of *Understanding Comics,* "…the phenomenon of observing the parts but perceiving the whole… is called *closure* (McCloud 63)." We have been conditioned to add closure to the visual elements that provide limited information. In Figure 5.4, Calvin is drawn without feet in three of the panels but the viewer automatically adds them assuming that they are there but hidden from view.

When the viewer sees each section of the *Impossible Vase*, he or she automatically completes the rest of the vase with expectations of it moving in the same direction. The effect of the *Impossible Vase* may not be so striking had the viewer not already had preconceived ideas of how the vase should behave. The visual system's tendency to create closure for perceived motion apparently lies in the viewer's familiarity of the physics involved in motion.

5.4 Betting on the Odds

The *Impossible Vase* owes its convincing illusion largely to the viewers' tendency to bet on the odds, a concept previously mentioned with the Ames Room. In Ames Room, the likelihood of the room being any shape other than rectangular seems so slim that the viewer is convinced that the people in there are disproportionate. The *Impossible Vase,* similarly, relies on the fact that the viewer finds it unlikely that the textures of the vase can move separately from its physical counterpart, therefore convincing the viewer that it is actually physically rotating in different directions rather than having the elements separated.

5.5 The Narrative

Generally, as spectators, we understand narratives in a linear fashion, usually moving forward in time. This is not surprising since we naturally experience time from one moment to the next and never backwards. Most cinematic productions also embrace this concept and usually show scenes faithful to the order that the events happen. Sometimes flashbacks in cinema or sports clip playbacks are used to guide the viewer in remembering key moments, but the viewer is rarely shown consecutive sequences outside the normal chronological order.[10] However, with many still art works, time is expressed in glimpses with no specific order and sometimes without a beginning or end.

Figure 5.5 David Hockney, *The Scrabble Game.* Photo collage, 1983.
The narrative of the collage is dependent on the viewer since there is no specified order on viewing each individual photo or section.

In Hockney's *Scrabble Game* (Figure 5.5), the viewer plays an active role in unfolding the story. The viewer can begin looking at this collage from any

[10] Several films have experimented with the chronology of presenting narratives. Two examples that come to mind are: *Pulp Fiction* and *Memento.* Pulp Fiction reveals its plots in short flashbacks in a non-consecutive order. *Memento* presents its narrative in short snippets with each consecutive clip portraying an earlier time.

point of his or her choosing. As one scans each photograph, a different moment in time is revealed. Hockney captures the idea that each moment that we *see* is unique and helps us form an impression of our surroundings. Our memory of events is formed not only by what we see but how we first perceived it.

In most narratives, the viewer relies on his or her memory to comprehend what the new scene means in relation to the previous one. In other words, our ability to comprehend a narrative is dependent upon our ability to relate the new visual information with the data we already have stored in our memory. The scenes stored in our memory are fragmented more like short snippets of information instead of long streaming videos. When the viewer recalls these images from memory, he is also called upon to reconnect one scene to the next. In each instance, a new gap is opened for interpretation. David Hockney's *The Skater* shows that memory's role in creating a narrative is more evident in perceiving object motion (Figure 5.6).[11]

[11] See Stephen Palmer's *Vision Science* for a detailed explanation of visual memory (Palmer 573-581). Although the viewer's interpretation of Hockney's collages does not fit perfectly into a specific category of visual memory, it is apparent that the narrative is created through several combined triggers.

Figure 5.6 David Hockney, *The Skater.* Photo collage, 1982.

This photo collage demonstrates the idea that the understanding of object motion is dependent on memory. Despite the object's motion in the three-dimensional world, its motion is registered as two-dimensional images on the retina recorded over time (Palmer 466-7).

With the *Impossible Vase,* the viewer recalls earlier scenes as he scans from one section of the vase to another. However, sometimes memory influences the expectancy of an upcoming scene. When the viewer sees one section of the vase, his preconceived ideas of how a vase behaves leads him to believe that the next section will be rotating in the same direction. When he realizes his expectations are not met, the narrative of the rotating vase becomes broken. He retraces his path to find where the chain has been broken.

5.6 Combined Visual Triggers of the Impossible Vase

The illusion of the *Impossible Vase* is created through several combined visual triggers. Many of these triggers require a higher level of cognitive thinking. From the viewer's first perusal of the vase, his limited visual angle allows the viewer to see only one portion of the vase at a time. During this period, the viewer's localized perception is consistent. Only through the saccadic movement of his eyes throughout the digital sculpture does the viewer realize that there appears to be some physical discontinuities. This conclusion is drawn from the comparison of the images he receives during the saccades of his eyes. The comparison, however, requires interludes of the viewer's memory to create a reference image for the comparison of the current visual information the viewer's gaze holds. From this point on, memory becomes a paramount influence in the illusion of the impossibly twisting vase.

The *Impossible Vase,* like all narratives, tells a story. However, the means of communicating this narrative is different than the usual animation clips that we have seen in our daily lives. Much like Hockney's *Scrabble Game,* the story is dependent upon the viewer. It is the viewer who brings in the expectations and preconceived conditions to the narrative of the vase. The viewer is given the freedom to start his gaze in any location of his choosing – from the flower, to the vase, to the textures, etc. He is in control of the way he is experiencing the narrative. When the viewer finds that the vase does not behave to his expectations, he does not realize that his own visual system is the greatest contributing factor to the illusion but ascribes the inconsistency to the vase instead.

Although there may be several explanations as to why our visual system accepts the *Impossible Vase,* one explanation is from the viewer *betting on the odds* on the behavior of the vase. When the viewer sees the twisting vase, there follows several steps of thought. First the viewer is cued in by the projected textures that the vase is twisting. To verify the accuracy of his theory, the viewer looks to the physical contours of the vase for further support. Contrary to the viewer's expectations, the body of the vase is not twisting. At this point, the visual information he receives is at a deadlock. The viewer's cognitive mind takes over betting on the odds of what is more likely to be true. Since it seems less likely for the vase's textures to be separated from its physical body, the viewer concludes that the vase is actually twisting.

Chapter 6

Conclusion and Future Implications

6.1 Computers, Perception, and Art… Oh, my!

Contrary to today's exclusive nature of specialized disciplines, the role of the artist/engineer or artist/scientist was often fulfilled by the same person in the past. Exemplary historical figures such as Leonardo da Vinci or René Descartes[12] have amalgamated information from their studies in both the sciences and the arts to reach new levels of understanding. Only in recent times have these disciplines branched off into complete separate areas of study and perhaps forgotten the benefits that one can offer the other. If we can keep ourselves from drowning in the convoluted associations of fiber optics, CPU's, and Gigahertz computational power to the age of technology, we can perhaps take a step outside of the proverbial box and concentrate on how the digital revolution can help us move towards the future.

With the ever-increasing advancement of technology, it is no surprise that attention is now turning toward Perception in Computer Graphics. Emulation and control of the human body or certain biological tasks no longer seems so farfetched, while Computer Graphics always appeared to be one

[12] Descartes, best known for his mathematical contributions, also wrote in the mid 17th century about the process of the human visual system flipping the image on the retina. See Martin Kemp's *Visualizations: the Nature Book of Art and Sciences* for more listings on cross-disciplinary research among western society's well known scientists and artists.

step away from having more influence on the human visual system. Art, on the other hand, has attempted to guide human perception for its own purposes since the beginnings of human history and now serves as a template for machines to achieve similar goals. In turn, the new technology age has created a vast uncharted area for art to explore new means of expression.

6.2 Perception Research Directing the Viewer's Gaze

Perception research in computer graphics has been primarily involved in the rendering phase of the computer image production pipeline. Current applications include virtual simulations and other immersive environments. The goal of physically accurate renderings may be more beneficial to scientific simulations than it is necessary for simulating what the human visual system records. Flight simulations, for example, take advantage of the difference between foveal and peripheral acuity for their displays. With devices such as head-mounted displays (HMDs), software programs are able to track the viewer's gaze and create images of appropriate resolution accordingly.

Recent computer graphics research has also adapted rendering techniques to include perception-based algorithms to reduce rendering time. For example, these algorithms take into consideration the human visual system's inability to absorb details while the subject is in motion, or its natural focus of attention to highly irregular shapes or highly contrasted areas.

Although the *Impossible Vase* does not deal with these concepts, it clearly points to several perception issues that can be adapted to rendering algorithms. For example, field of view and localized perception issues covered in the previous chapter can be introduced to the rendering model to direct the viewer's gaze. Currently, hierarchical rendering models have been conceived based on where the viewers look at, but there are no rendering models that take advantage of perception-based algorithms to assist in directing the viewer's gaze. On the creator's end of the process, computer graphics research lends very little control on the focus of a scene, which is usually open to the discretion of the viewer rather than the creator. In cinematography, the lighting director can create certain areas of focus by lighting the main subject differently from the rest of the scene. Such concepts can similarly be applied to rendering in computer graphics by rendering the focus areas of a scene using perceptual-based guidelines. The re-insertion of the user as the artist/creator should be an area to be expanded on rather than minimalized.

6.3 Conclusion

"Art is not what you see, but what you make others see."

- Edgar Degas

As an investigation on the human visual system, one of the most important points that the *Impossible Vase* tries to bring to our attention is that *how* we see is as important as *what* we see. For generations, artists have been trying to manipulate the way we see things from the romanticized paintings of Georges Seurat to the comical jumbo food sculptures of Claes Oldenberg. In each instance, the artist exercises his will to guide the viewers to see what the artist intends them to see.

In computer graphics, however, images are created to cater to what the viewer wants. The viewer takes a passive role in the visual experience. Perhaps the next step in interactivity is to create a more passive-aggressive visual experience. The viewer's gaze has always been an important aspect in art. With new research in Perception Psychology and the Human Visual System, the viewer's gaze can be guided as well in computer graphics.

One may perceive that such puppetry over the viewer's attention is beyond the reach of current technology, but looking back at what traditional masters have done with simply oils and a paintbrush, such goals are not beyond the scope of current computer graphics research. Technology, after all, is nothing but a new medium for the artist to express himself. The need to go back to the basics and discover the nuances that drives the human visual system will help computer graphics broaden its expressiveness in new fields in design, visualization, education and teleconferencing as well as animation and entertainment. These investigations will also bring explorations of art together with the sciences that drive the way we see.

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