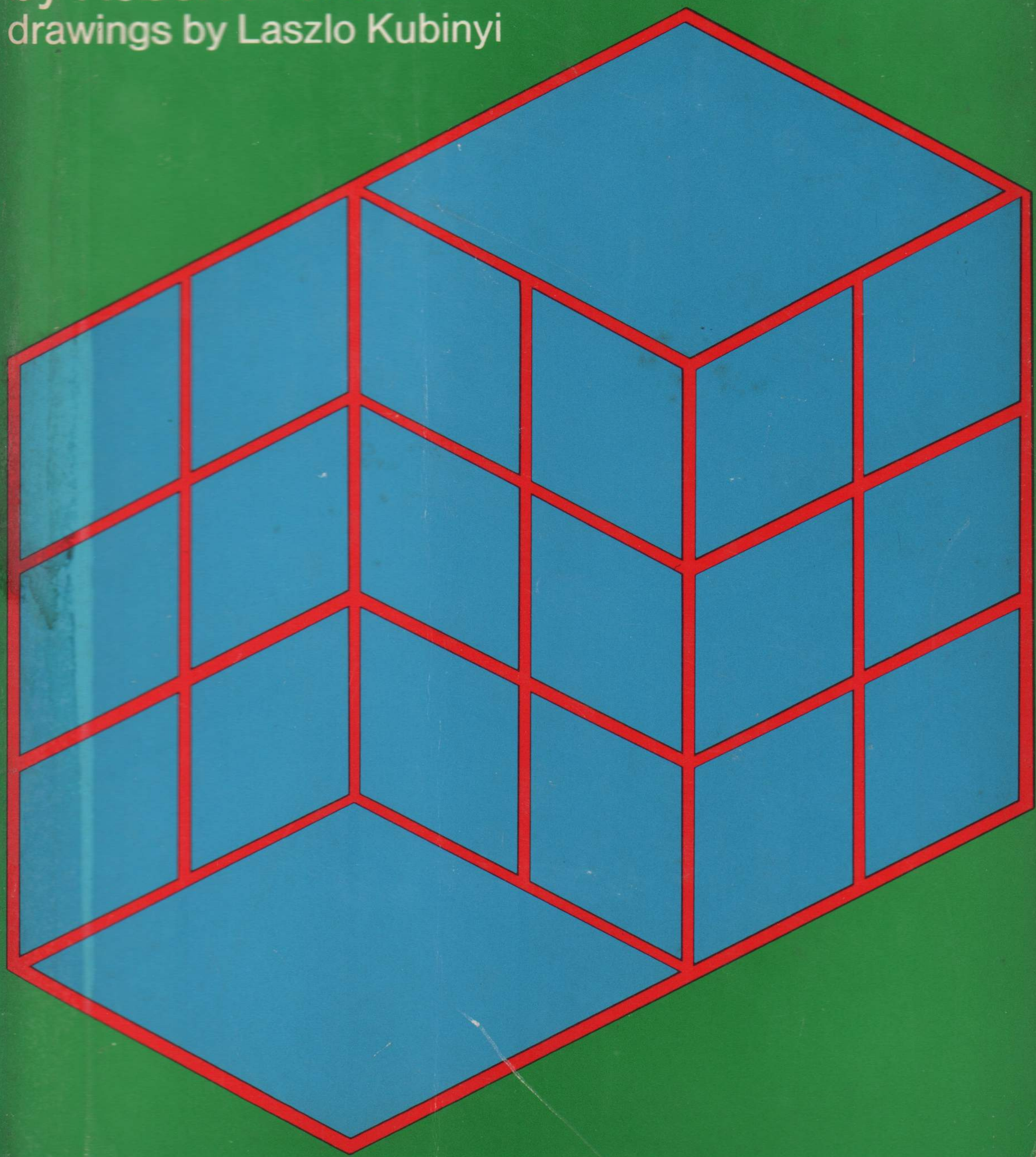
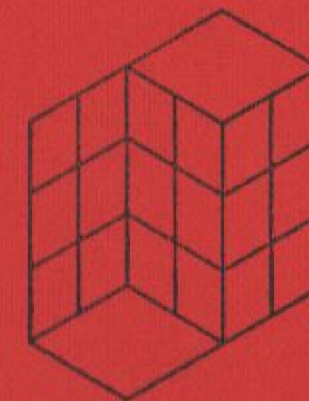
Science, Art, and Visual Illusions

by Robert Froman

drawings by Laszlo Kubinyi





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to Gary Zucker

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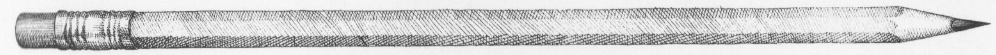

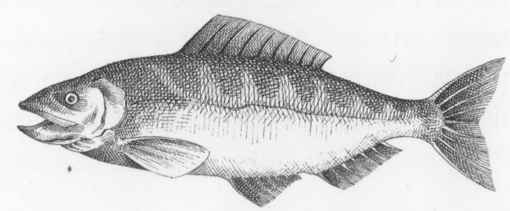

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R. F.

Introduction

In some ways science and art are decidedly different, but they are not nearly as far apart as they often are thought to be. One good way to see how they blend into each other, and can even depend on each other, is to consider how they deal with visual illusions.

Everyone who can see has experienced visual illusions, but a fascinating thing about them is that they are very difficult to define. Many writers of textbooks on physics, art history, psychology, or philosophy used to feel that they had to try. The definitions they wrote were not very helpful.

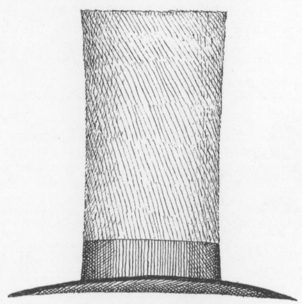
"Mistakes in seeing" was one definition.

"False perceptions" was another.

"Obviously misleading perceptions" was a totally confusing effort. If it is obvious to you that you are being misled, why go astray?

"Subjective perversions of the contents of objective perceptions" was one of the more pompous efforts to define the phenomena. It is useless as a definition, but the phrase "objective perceptions" is worth a long look. This phrase expresses a belief almost everyone shares without ever considering the possibility that it might be false—the belief that what we see is whatever is "out there" before our eyes. In fact this is not true.

Consider this drawing:



You can see that this is an old-fashioned stovepipe hat and that its height is greater than its width at the brim. Or can you?

It certainly seems that the vertical lines are longer than the horizontal lines at the bottom. But take a ruler and measure. Or, if you do not have a ruler handy, take a piece of paper, hold one edge of it along the bottom of the hat, and mark off the length of the horizontal lines. Now turn the paper around and hold this marked-off length against one of the vertical lines.

When you have done this, you have performed a scientific test. The result is typical of the results of countless such tests. Again and again, the results of scientific tests have contradicted beliefs that had seemed so obviously correct that no one had bothered to test them.

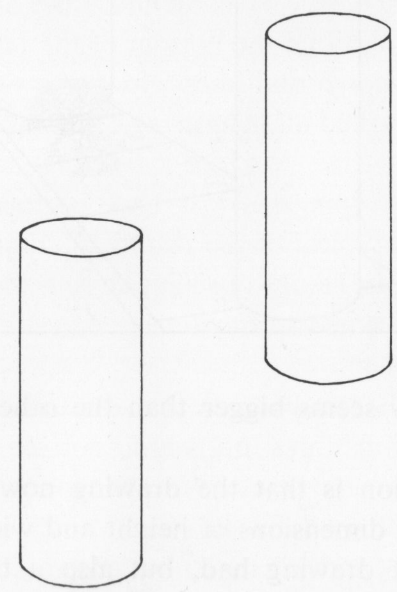
The stovepipe-hat drawing creates a visual illusion. In doing so, it vividly demonstrates that we do not see exactly what is "out there" before our eyes. We see, for reasons that will appear later, what we *learn* to see.

Many scientists and artists have become sharply aware of

this. They also have learned that they can better understand why it is so by studying visual illusions. Those studies are the subject of this book. They raise exciting and fundamental questions about the relationship between what goes on outside our skins and what goes on inside them. Consequently, a definition of the term *visual illusion* will have to be postponed until we have examined some of these questions.

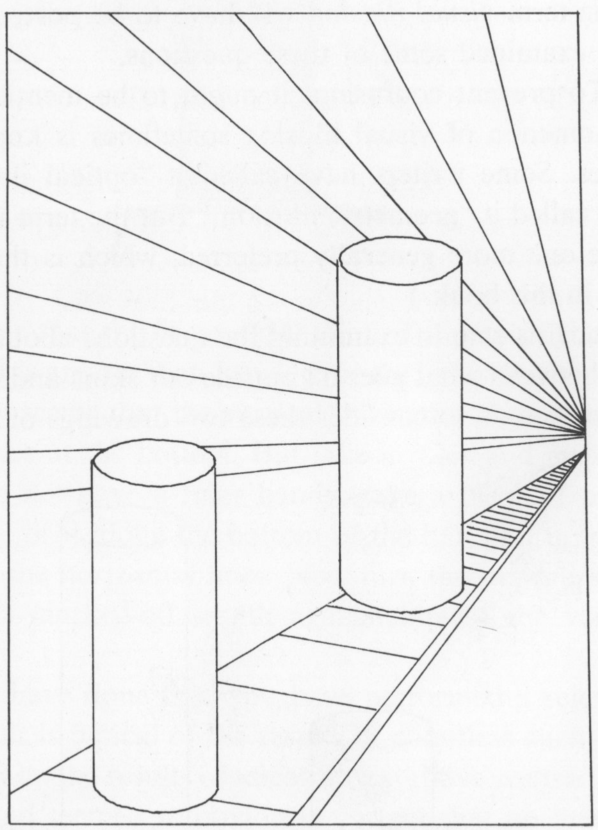
(To prevent confusion, it ought to be mentioned that the phenomenon of visual illusion sometimes is known by other names. Some writers have called it "optical illusion." Some have called it "geometric illusion." But the term *visual illusion* is the one more generally preferred, which is the reason it is used in this book.)

Our first step in examining the questions about the relationship between what goes on outside our skins and what goes on inside them is to consider these two drawings of posts:



They look the same size. And they are the same size. You can convince yourself of this with the help of a ruler.

But now, without making any changes in the posts, surround those drawings with other lines:



One post now seems bigger than the other. How can we explain this?

The explanation is that the drawing now seems to have not only the two dimensions of height and width, which were all that the first drawing had, but also a third dimension,

depth. To see three dimensions while looking at a flat, or two-dimensional, surface is to experience a visual illusion.

Scientists have been able to explain how this illusion of depth works and why it makes one post seem bigger, but it was from artists that they got their first clues. Artists began working with depth illusion thousands of years ago. It is by looking at the works of art they have created that the rest of us have learned to see in ways that lead us to experience that illusion.

The first purpose of this book is to show why this is so and how it helps to explain visual illusions in general. The additional purpose is to show how understanding visual illusions helps us to gain startling new understanding of how we see in general, to improve our use of our eyes, and to increase our pleasure in using them.

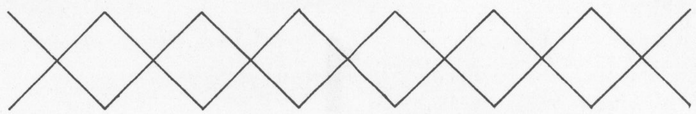
1

The Illusion of Depth from Prehistoric Pottery to Modern Art

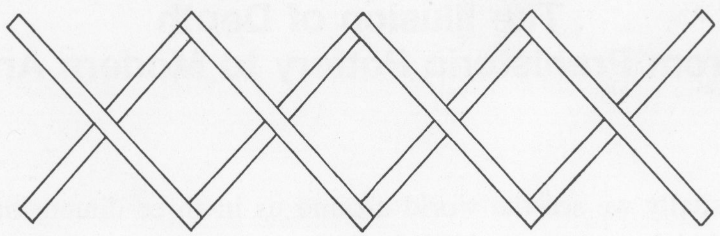
Usually we see the world around us in three dimensions—with height, width, and depth. But most paintings are flat surfaces with only two dimensions—height and width. For some purposes painters have found these two dimensions all they need. For other purposes they have wanted to add a third dimension to their paintings. To do this on a flat surface it is necessary to create the illusion of depth.

It was in Europe during and after the fourteenth century A.D. that painters were most concerned with creating depth illusion. They devoted a great deal of time and effort to finding ways of doing so. Many histories of art give the impression that this was the first time artists had concerned themselves with the depth illusion. This is far from true.

One of the ways of creating the illusion was known in prehistoric days to people who made designs on pottery. The oldest known pottery designs seem to have had only two dimensions, like this:



But it was not long before the potters found a way to give their designs depth, like this:



The bars running from upper left to lower right seem to obscure the centers of those running from lower left to upper right. We know from experience that when one thing is closer to us than another in line with it, the former obscures part of the latter. So in this design it seems that the upper-left-to-lower-right bars are closer to us than the others. This is what persuades us that the design has depth—very slight depth, to be sure, but nonetheless a distinct third dimension.

Some of the famous cave paintings dating from Europe's Paleolithic Period, ten thousand to thirty thousand years ago, create an illusion of much greater depth, as can be seen, for example, in Figure 1.

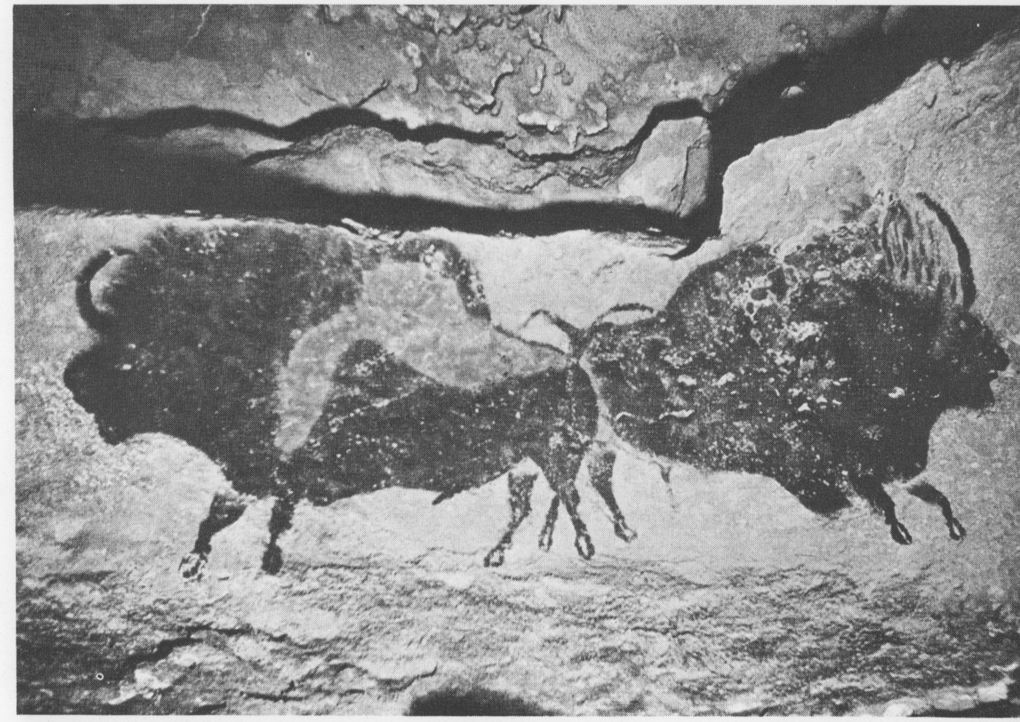


Figure 1. *Two Bison*, Lascaux Cave, France, Reproduced from *Palaeolithic Art* by Paolo Graziosi, by permission of the author.

The painter of these bison created the illusion of depth by means of the same technique used by the maker of the pottery design above. He shows, for instance, the left side of the bison on the left, including all of both left legs. But only the lower parts of its two right legs are seen, the upper parts seeming to be hidden behind the body. In addition, the hindquarters of the bison on the left seem to block our view of the hindquarters of the bison on the right. This creates the illusion that the painting is at least two bison deep.

Not until about 400 B.C. did painters go much beyond this in trying to make two dimensions seem like three. Some Greek artists then became so successful at making their paintings seem to have depth that they provoked the philosopher Plato to angrily denounce their works as "nothing short of witchcraft."

Most of what we know of the works of the Greek painters is what Plato and other ancient writers had to say about them. The paintings themselves have been destroyed by time, vandals, or religious fanatics. But some works done by Roman painters who imitated the Greeks have been preserved. This is chiefly the doing of the volcano Vesuvius. In 79 A.D. it erupted and buried under several feet of ash the cities of Pompeii and Herculaneum and much of the surrounding countryside near what is now Naples. The walls and, in some cases, even the floors of many of the city buildings and country villas were decorated with paintings for which volcanic ash turned out to be an excellent preservative.

Figure 2 is a detail from a Pompeian mosaic (a painting made from bits of colored stone cemented together) which shows the defeated Persian King Darius. The mosaic is a copy of an older Greek painting of Alexander the Great's victory over Darius at the battle of Issus. It uses a way of reinforcing the illusion of depth that apparently was unknown to pre-Greek painters.

Part of the illusion here is brought about merely by elaborating on the means used by the Paleolithic painter of the two bison. But instead of only one animal behind another, this mosaic presents a depth of several layers: the horse in the foreground, the soldier holding its reins, behind him the side of Darius' chariot, behind that Darius himself, behind Darius his charioteer, and behind the charioteer a foot soldier who partly obscures another soldier behind him.

Figure 2. Detail from *Battle of Issus,* courtesy of Fratelli Alinari, Florence.

What is new is the way the foreground horse is drawn. The cave painters depicted their animals in side views. We see this horse from the rear; his hindquarters blot out most of the rest of him. His head and neck are visible only because of the way they twist off and up to the right. This manner of painting the animal adds the whole length of a horse to the illusion of depth in the picture.

Some Pompeian wall paintings attempted to create illusions

Figure 3. The Metropolitan Museum of Art, New York City.

of even greater depth than this. Indeed, the whole purpose of many such paintings was to create the illusion that the wall was not a wall but an opening into a grotto or onto a wide vista. Figure 3 is a photograph showing the original walls of a *cubiculum* (bedroom) in Boscoreale, a suburb of Pompeii. The paintings date from 40–30 B.C.

These paintings look remarkably like some of the work done by painters of the fourteenth century and later. But at just this point in the development of depth illusions ancient artists began to lose interest in it. They turned instead to two-dimen-

sional symbols. From a century or two after Pompeii's burial under the ashes of Vesuvius until the fourteenth century, artists almost always arranged the figures in their paintings to indicate not where the figures stood in space but how important they were. The thirteenth-century Italian work shown in Figure 4 is a good example.

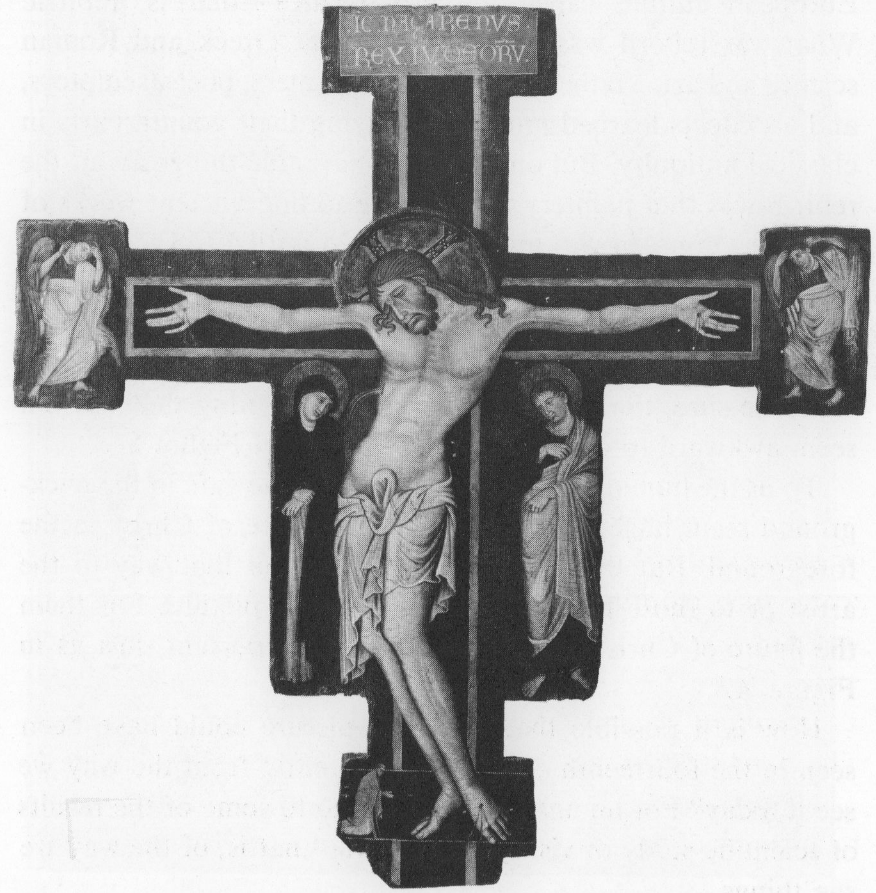


Figure 4. *Crucifixion*, by a Master of Saint Francis.
Philadelphia Museum of Art: W. P. Wilstach Collection.

The artist worked out the sizes and positions of the figures solely for the purpose of showing the relative religious importance of each of them. The Christ figure dominates; next in importance are the Virgin Mary and Saint John on either side of the Christ figure. The angels at the ends of the crossbar come next. Last, and decidedly least, is the human being at the foot of the Cross.

With the fourteenth century began the great flowering of European culture called the Renaissance—that is, rebirth. What was reborn was interest in ancient Greek and Roman science and art. Mathematicians, astronomers, poets, sculptors, and architects learned much by studying their counterparts in classical antiquity. But one of the remarkable things about the rebirth was that painters were unable to find ancient works of their art (Pompeii was not rediscovered until 1748), yet soon were busy working out for themselves the same techniques for creating the illusion of depth that had fascinated ancient Greek artists and their Roman imitators.

To be sure, the first new attempts at creating that illusion seem awkward to us now as, for example, in Figure 5.

To us the human figures emerging from the gate in the background seem huge, far larger than the figure of Christ in the foreground. But they certainly did not seem that way to the artist or to those for whom he painted the picture. For them the figure of Christ was overwhelmingly important, just as in Figure 4.

How is it possible that the same picture could have been seen in the fourteenth century so differently from the way we see it today? For an answer, we must go to some of the results of scientific study of visual perception—that is, of the way we see things.

It is obvious that Simone Martini had broken with the

Figure 5. *Christ Carrying the Cross*, by Simone Martini. The Louvre Museum, Paris.

medieval tradition of making the most important figures the largest ones. It is clear, too, that he meant to create an illusion of depth, awkward though his attempt seems to us. Why, then, did he make the background figures so big? To us it is clear that they should have been made much smaller in order to appear human size instead of gigantic. Simone Martini simply did not realize this. Strange though it seems, he painted the figures exactly as he saw them.

Our way of seeing things around us seems laughably simple and obvious until someone tries to explain it. For instance, a person might see a book lying on a table, walk over to the table, and pick up the book. We perform acts like this hundreds of times every day, and so they seem very simple. Actually, they involve complex interactions between, as it was described in the introductory chapter, what goes on outside our skins and what goes on inside them.

Some of the ancient Greeks thought, and many people still think, that we see by darting out rays from our eyes. The comic-strip hero Superman is supposed to be able to see through solid walls by sending X rays from his eyes through the walls. This is a mistaken notion. Seeing is a matter of taking something in, not sending something out.

But when a person "takes in" a book lying on a table, he obviously does not literally take the book and put it in his head. What he does take inside his head is light reflected by the book and the table. This light strikes the back of his eyeball, called the retina, and forms on the retina an image which resembles the pattern of the book and the table.

As will be explained later, a person does not see the image on his retina. It is only a sort of preliminary stage in the seeing process. But here it is this preliminary stage that needs to be examined in order to understand why Simone Martini could

not automatically create an illusion of depth.

When you look at someone five feet tall or larger standing only a couple of feet from you, the image of him covers most of your retina. But if you or he moves away until you are twenty feet or so apart, the image of him covers a much smaller part of your retina. *Yet you do not see him as smaller.*

This too involves a point to be explained in more detail later—the point that most of the act of seeing takes place in the brain, which receives and interprets messages from the eyes. Stored in your memory is the information that a person does not change in size when he moves away from you, so you do not see any change in his size. This is a habit of seeing that scientists call *size constancy*. It enables you to ignore the size of the image on your retina and pay attention to what you know from experience.

To get an idea of the strength of the size-constancy habit, look at someone about twenty feet away. He looks the same size as he does when he is right next to you. Now close one eye and hold a full-length pencil vertically at arm's length between you and the person, and compare its length with the person's height. The pencil's length is greater—that is, it forms on your retina an image longer than the image formed by the person across the room.

Here is another way to demonstrate the size-constancy habit. Find a room ten or twelve feet wide, with light, uniformly colored walls. Stand about two feet from one wall. Place a black button or something similar on a nearby white tabletop or a blank sheet of white paper. Stare at the button for half a minute. Now look at the wall nearest you.

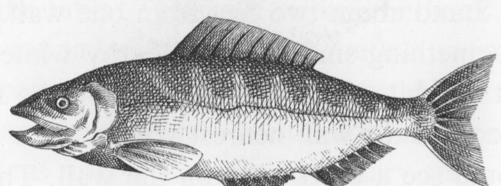
You should see a black spot on the wall. This is called an *afterimage*. By staring at the button, you formed on your retina what can be thought of as an impression, an impression that lasts for several seconds after you stop looking at the button. When you look at the wall, the light reflected from the wall mingles with the afterimage on your retina so that you "see" the afterimage as a spot on the wall.

But now look at the wall across the room from you (which should be four or five times as far away as the first wall). Once again you should see a black spot on the wall—but this time it will seem much larger than before.

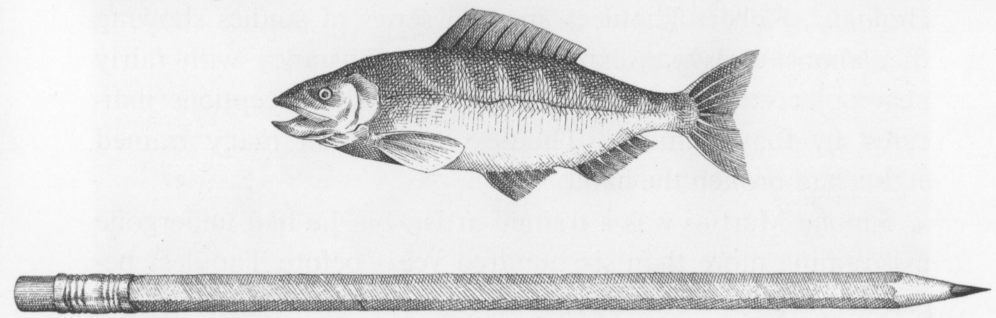
The size of the impression on your retina has not changed. All that has changed is the distance of the wall on which you "see" that impression as a spot. You know from experience that if two objects take up the same area on your retina, and one of them is farther away, then the farther one must be the larger. So you "see" it as larger.

To be sure, size constancy breaks down at great distances. When you are on top of a tall building or looking out of an airplane, people and automobiles and houses and other familiar things look very small. "No bigger than ants" is a common way of describing such objects in such scenes. But the first time this breakdown in size constancy occurs, it is a startling experience—a further indication of the strength of the size-constancy habit.

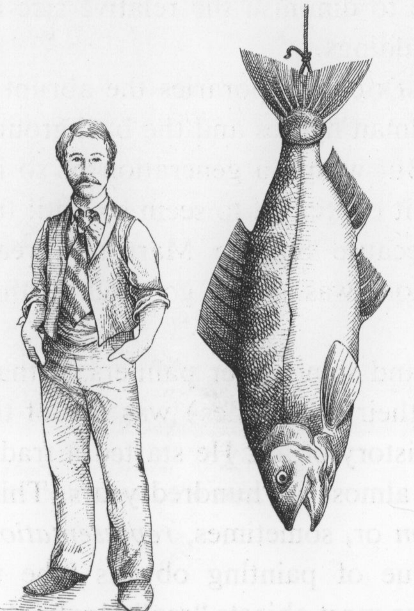
Another interesting point about size constancy is that it works only if you are familiar with the sizes of the objects involved. Here is a drawing of a fish:



There is no evidence in the drawing to indicate the size of this fish. It could be any of a wide range of sizes. But place it beside a pencil:



Now it seems obvious that the fish must be a minnow. But the same fish drawing seems enormously larger when placed beside a drawing of the figure of a man:



Although the existence of size constancy has been known for centuries, it was not until the 1930s that it became the subject of detailed scientific investigation. Then a British psychologist, Robert Thouless, made a series of studies showing that almost everyone experienced size constancy with fairly near objects. What interests us here are the exceptions indicated by that "almost." Thouless found that many trained artists had broken the habit.

Simone Martini was a trained artist, but he had undergone his training more than six hundred years before Thouless began his studies. What enabled artists of the 1930s to break the habit was a long series of experiments in painting of which *Christ Carrying the Cross* was one of the first. What makes the figures emerging from the gate seem out of scale is that Simone Martini was still in the grip of the habit in much of his seeing. He gave the human figures the size he "knew" they had, though he did manage to diminish the relative size of the walls and roofs of the buildings.

For the artist's contemporaries the abrupt change in scale between the human figures and the background buildings was unimportant. But within a generation or so it began to seem awkward, and it continued to seem so until this century. This was chiefly because Simone Martini's great contemporary Giotto di Bondone was able to go much further toward breaking the habit.

Giotto (he and some other painters of that period usually are known by their first names) was one of the greatest innovators in the history of art. He started a tradition in painting that lasted for almost six hundred years. This tradition often is called *realism* or, sometimes, *representationalism*. It refers to the technique of painting objects "the way they really look." And since most objects "really look" three-dimensional,

Figure 6. Detail from *Joachim's Dream*,
by Giotto. Courtesy of Fratelli Alinari, Florence.

Figure 7. *Madonna and Child Adored by Angels, Saints, and Federigo, the Duke of Urbino,* by Piero della Francesca. Courtesy of Fratelli Alinari, Florence.

this tradition of painting puts great emphasis on creating the illusion of depth.

How Giotto happened to break the size-constancy habit no one knows. He certainly did not suddenly start painting all objects exactly "the way they really look." But he just as certainly did create a new and stronger illusion of depth by making the figures he wanted to appear in the foreground larger than the figures he wanted to appear in the background.

In Figure 6, for example, the shepherd on the left seems to be behind the one on the right. You can see that the one on the left is smaller in scale. The sheep too dwindle in size and seem to recede, though the dog behind the farthest sheep seems unnaturally large. The illusion of depth seems a little awkward to us, but more convincing than in *Christ Carrying the Cross.*

After Giotto many painters experimented in creating the depth illusion. One of the leading experimenters in the fifteenth century in Italy was Piero della Francesca. He was interested in mathematics as well as painting and eventually worked out some of the mathematical laws of what came to be known as *perspective*. These laws explain how figures should be drawn and arranged on a flat surface in order to create an illusion of depth. For our purposes here it is sufficient just to see how Piero put his ideas into practice (see Figure 7).

When you compare this painting with Giotto's *Joachim's Dream,* Giotto's ways of suggesting depth seem to be either awkward or appealingly innocent. The illusion of depth created by Piero is commanding.

Giotto's painting shows only two human figures, one behind the other. Piero's shows many figures receding—five on the left and six on the right. Notice how each figure is a little shorter than the figure in front of it. The figure that seems farthest away on the left is only seven-tenths the height of the foremost figure on the left. Notice how the figures' heads gradually become smaller with distance; even the eyes and mouths of those toward the rear are smaller and less distinct than the features of those in front. Many details make the niche seem deep: the ins and outs of the molding, the twists and turns of the wall panels, the egg that seems to hang inside the niche, and the shadow from the left wall that seems to fall into the interior of the niche. All of this contributes to the illusion of depth.

The fifteenth-century Flemish master Jan van Eyck used an even greater variety of ways of creating the illusion of depth in his famous painting shown in Figure 8.

Here the chandelier has an effect similar to that of the egg hanging from the ceiling of Piero's niche, but van Eyck made the chandelier more persuasive by making it seem to have three dimensions of its own. There is no one big shadow such as that cast by the left wall into Piero's niche, but several less conspicuous ones have a similar, more subtle effect. Also more subtle is van Eyck's arrangement of figures. Whereas Piero arranged one human figure directly behind another, van Eyck places the little dog in the foreground, the bride and groom next behind him, the bed and the window in the middleground, and the chair and the wall in the background. To cap the subtlety, the mirror on the rear wall reflects the backs of the human figures.

But strongest of all in the service of the illusion is the way van Eyck drew the straight lines of the floorboards, the ceiling and the sides of the scene. To understand what he had to know about the way we see in order to convey the impression that parallel lines are receding in space, try this experiment.

Hold a rectangular sheet of paper—such as an eight-and-a-

Figure 8. *The Marriage of the Arnolfini*, by Jan van Eyck. Reproduced by courtesy of the Trustees, The National Gallery, London.

half-by-eleven-inch sheet of typing paper—vertically at arm's length. You can see quite clearly that the left and right sides are parallel, the same distance apart at the top as at the bottom.

Now lay this sheet of paper on a table in front of you and look at it with one eye. Unless you have had experience in the techniques of realistic painting, the two sides of the paper will continue to seem parallel. Still looking only with one eye, take a pencil in each hand, place the eraser end of one pencil at the bottom left corner of the paper, and place the eraser end of the other at the bottom right corner. Hold the pencils erect and align them with the sides of the paper. Now look at the pencils with both eyes open. The amount by which the pencils slant toward each other will astonish you.

You may need a ruler to convince yourself that the lines that appear parallel in van Eyck's painting, such as those of the floorboards, actually do slant toward each other, just as the pencils did in your experiment. The reason this works so well in the service of the depth illusion has to do with a companion habit to size constancy. This one is called *shape constancy*. In looking at actual objects, we unconsciously ignore the effect of distance on shape as well as on size. But if a painter wants to re-create the appearance of a scene in three dimensions, he must ignore his knowledge that shapes, as well as sizes, do not change with distance, and he must concentrate on how shapes appear to change with distance. Parallel lines, for instance, appear to converge in the distance.

Piero and van Eyck sought in these paintings to create illusions of only a few feet of depth, but painters were not long content to stay indoors. Creating an illusion of depth as great as that of all outdoors was no simple matter, however. Figure 9 shows one of the early attempts.

The artist obviously had trouble making a transition from

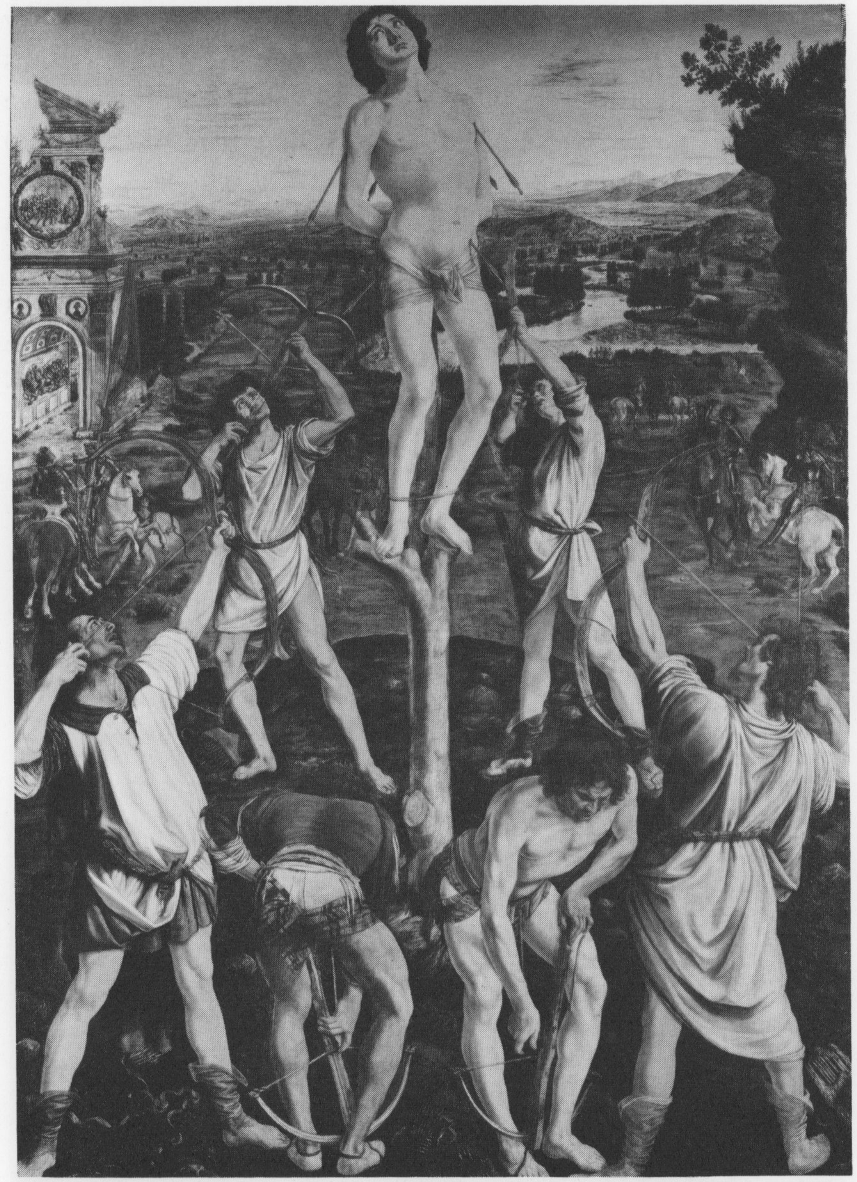


Figure 9. *The Martyrdom of Saint Sebastian*, by Antonio Pollaiuolo. Reproduced by courtesy of the Trustees, The National Gallery, London.

foreground to background. He tried to solve his problem by making the foreground a little hill, the brow of which obscures the middle ground, so that there is a clumsily abrupt change of depth from the rearmost archers near the brow of the hill to the nearest horsemen on the plain below.

Painters soon overcame difficulties like this, though it was not until the rise of the school of painters of landscapes for their own sakes (rather than as backgrounds) that the depth illusion in painting reached its maximum development. In the landscape by Jacob van Ruisdael of seventeenth-century Holland, it is overwhelming (Figure 10).

Figure 10. *Wheatfields,* by Jacob van Ruisdael. The Metropolitan Museum of Art, New York City. Bequest of Benjamin Altman, 1913.

The illusion here is not merely that the flat surface of the picture has depth, but that it stretches to infinity. It leads the eye and the imagination along the road, through the little grove of trees, and endlessly on.

Ruisdael used an ingenious device, a sort of road tributary, to make his road's sides seem almost as far apart as the sides of the canvas at the base of the painting. To leave something to the imagination of viewers, he cut off the road by placing the tree grove across it before the point at which the sides would run together. But the lines of the tops of the slight rises to the left and right are indicated as running together at a vanishing point behind the tree grove.

Another reinforcement of the depth illusion is the way texture changes in the painting. In the foreground Ruisdael painted many more details of wheat stalks, roadside grasses, ruts, stones and such than in the middleground, and more in the middleground than in the background. This is the way we see actual landscapes—with much detail close up and with less detail as the distance increases.

Not visible in a black-and-white reproduction is the way color changes with distance. Air filters out colors toward the red end of the spectrum but lets through the blue end, so that the greater the distance light travels, the bluer it looks. That's why a clear sky and distant mountains look blue. An artist can help us see one section of a landscape as far distant by painting it a proper hue of blue.

For six centuries painters reveled in these ways of creating the illusion of depth. Even those who felt the need to distort some details in order to express what they felt about their subjects usually wanted to be realistic enough to indicate a third dimension. The Spanish painter El Greco elongated his human figures but kept them in perspective (see Figure 11).

Figure 11. *Christ at Gethsemane*, by El Greco. The Toledo Museum of Art, Toledo, Ohio. Gift of Edward Drummond Libbey, 1946.

Untaught painters, often called *primitives,* learned enough about perspective from merely looking at the paintings of others to be able to suggest depth at least some of the time. Figure 12, a painting by the early-nineteenth-century Ameri-

Figure 12. *Peaceable Kingdom*, by Edward Hicks. Philadelphia Museum of Art. Photograph by A. J. Wyatt, Staff Photographer.

can Edward Hicks, is an example of this school of painting.

The figures in the right foreground are completely out of proportion to one another, but the opening off to the left establishes an illusion of great depth.

Most of the French painters in the first wave of the nineteenth-century revolt against "official" art also stuck to the tradition of giving depth to their canvases by painting in perspective. These were the Impressionists, among whom Pierre-Auguste Renoir was one of the most prominent. Although he ignored many aspects of the "realistic" tradition, he often

Figure 13. *Le Moulin de la Galette*, by Pierre Auguste Renoir.
The Louvre Museum (Jeu de Paume), Paris. Permission S.P.A.D.E.M. 1969 by French Reproduction Rights, Inc.

worked as hard at creating the illusion of depth as did any Renaissance painter (see Figure 13).

But at this point in history the development of photography and the dull, repetitive quality of the work of many painters began to undermine the tradition of painting launched by Giotto. Artists and scientists with original turns of mind found that it was possible to reconsider that tradition instead of accepting it without question.

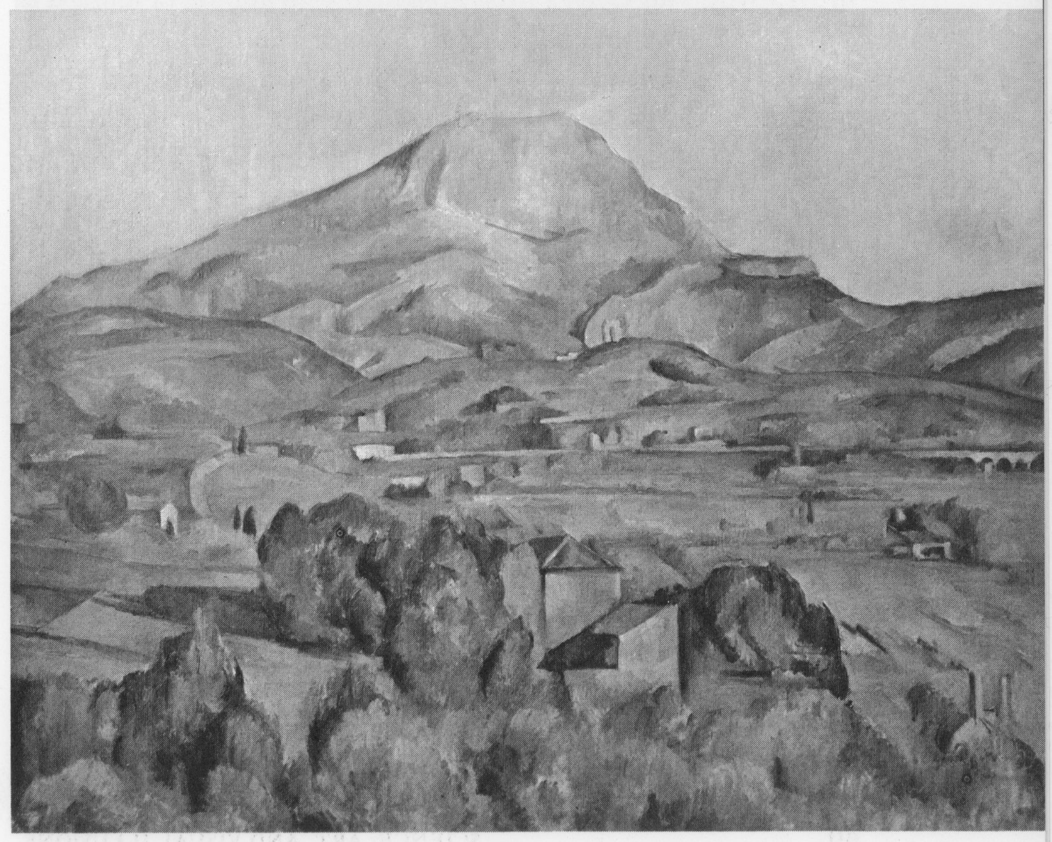
Artists were the leaders in this reappraisal, and two of the

foremost were Paul Cézanne and Vincent van Gogh. Neither completely rejected the depth illusion. Instead, they used those aspects of the illusion which seemed appropriate for any given work and ignored the others.

Compare the landscape by Cézanne in Figure 14 with van Ruisdael's *Wheatfields* (Figure 10).

Cézanne has created an illusion of depth, chiefly by making the buildings and the trees smaller and smaller as they "recede"

Figure 14. *Mont Saint Victoire Seen From Bellevue*, by Paul Cézanne.
Copyright © 1969 by The Barnes Foundation, Merion Station, Pennsylvania.



into the background. But the illusion has a minor role in this picture compared to its role in *Wheatfields*. What interested Cézanne more than depth, and what he sought to communicate to viewers, was the solidity and firmness of the forms in this scene, the clarity of the light, and the harmony of the arrangement. He paid no attention to details which did not convey these qualities.

Van Gogh was quite different from Cézanne in personality and painting style, but the two were in perfect agreement on the need to ignore any part of the tradition of painting in perspective that did not help them to express what they wanted to express. Compare the painting by van Gogh shown in Figure 15 with van Eyck's *Marriage of the Arnolfini* (Figure 8).

Van Gogh's room has about the same depth as van Eyck's, and van Gogh employs some of the same methods van Eyck used to make two dimensions seem like three. But the effect of van Gogh's room is completely and deliberately different. Van Gogh left out many of the kinds of details van Eyck so lovingly portrayed. There are, for instance, no shadows in the van Gogh painting, and several details are distorted out of perspective. The seats of the chairs even seem to tip toward the viewer as if inviting him to sit down.

"To look at the picture ought to rest the brain or rather the imagination," van Gogh wrote in a letter to his brother Theo. "The broad lines of the furniture . . . express inviolable rest. . . . This is my revenge for the rest I was forced to take."

Few of van Gogh's and Cézanne's contemporaries cared to look at their pictures, however. Though it is hard to believe today, when van Gogh's paintings are so popular that reproductions are given away in advertising campaigns, most people of his time who saw the paintings assumed that the distortions of "true perspective" were due to clumsiness. The long

Figure 15. *The Artist's Room at Arles*, by Vincent van Gogh.
The Louvre Museum (Jeu de Paume), Paris.

centuries of painting in perspective had blinded almost everyone to the idea that other styles of painting were possible and even desirable.

But there were some people who found the ideas and attitudes of Cézanne and van Gogh stimulating. By the 1890s several talented painters, and an increasing number of talented viewers, were actively seeking new ways of seeing. New ways of thinking were developing, too. This was the time when Western civilization was beginning to realize that people raised in different cultures have widely varying points of view about the world and life.

To take a simple and obvious example, consider snow. An Indonesian might read about it or see photographs of it, but it would be only a curiosity to him. To most Englishmen it is an occasional winter occurrence, notable chiefly as a source of pleasure for children and inconvenience for adults. To Eskimos it is so important that their language includes many different words for the many different kinds of snow—light or heavy, dry or wet, icy or sticky, solidly packed or loose, and so on.

Painting practices also varied from one culture to another. Westerners had discovered this is in the eighteenth century when a fad for Chinese art swept Europe. But Chinese painters, though their techniques differed from those of the West, often created some illusion of depth. What captured the interest of young Western artists at the end of the nineteenth century was traditions of painting that completely ignored the third dimension. The sixteenth-century Persian miniature shown in Figure 16 is an example.

Here the artist's primary intention was to create an intricate and pleasing decoration, not a representation of an actual scene. He paid no attention to perspective and tilted up the floor as if it were in the same plane as the wall. He made the human figures two-dimensional silhouettes instead of trying to suggest that they were rounded forms. Henri Matisse and other Western artists found in Persian paintings like this the inspiration for many experiments of their own.

But a far greater influence on Western artists was the art of

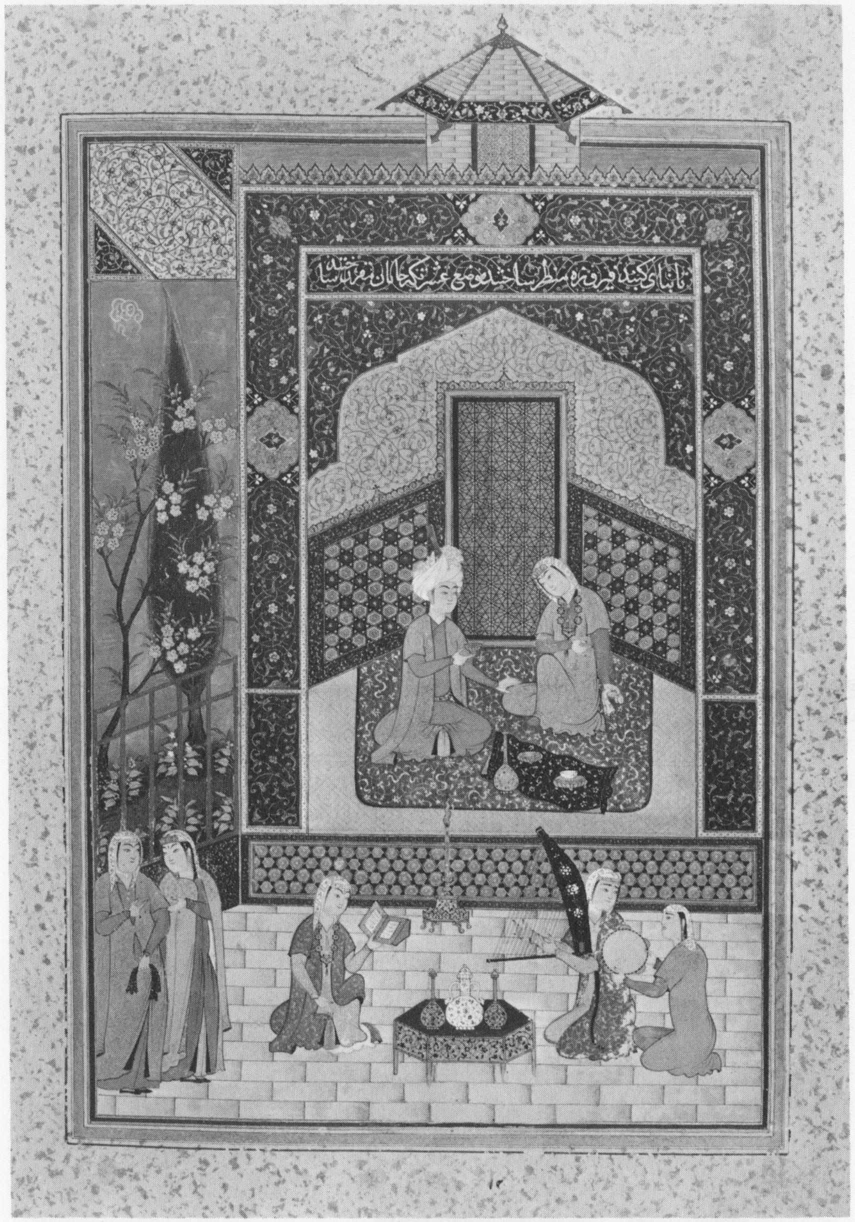


Figure 16. *Bahram Gur in the Turquoise Palace on Wednesday*. The Metropolitan Museum of Art, New York City. Gift of Alexander Smith Cochran, 1913.

so-called primitive peoples. (The "so-called" is because further studies have shown that the cultures of most such peoples are more sophisticated and complex than outsiders realized at first.) The African mask in Figure 17 is a good example.

This mask was made not to hang on a museum wall but to be worn by a participant in certain rituals. Like most works of art, it has an intensely realistic purpose—namely, to awe the audience at the rituals. Its maker knew that it would not serve that purpose well if he made its features closely resemble those of an actual human being. He deliberately exaggerated some parts of the features.

Today, distortion and exaggeration are common in art. We are so used to them that it is hard to realize what a liberating effect primitive art had on artists at the turn of the century. But equally interesting and exciting are some of the insights that scientists interested in perception have gained from studying peoples who produce such art.

In fact, it was at about the time when artists began concentrating on things other than the depth illusion that the scientific study of perception in general, and visual illusions in particular, slowly began opening up new possibilities.

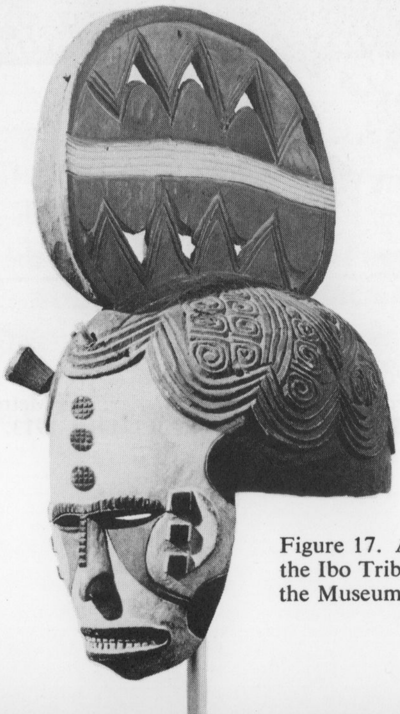


Figure 17. Ancestor Mask (Mmwo Society) of the Ibo Tribe, Nigeria. Courtesy of the Museum of Primitive Art, New York City.

2

Science's First Approach to Visual Illusions

Science involves four different kinds of activity.

First comes assembling the pertinent observations. Sometimes this seems very easy, involving nothing more than noticing that the sun rises in the east and sets in the west. Sometimes it can be very difficult, such as trying to observe the relationship between what goes on outside a person's skin and what goes on inside it.

The second step is forming a hypothesis—that is, making a guess at an explanation for the observations. Until a few hundred years ago almost everyone accepted the hypothesis that the reason why the sun rises in the east and sets in the west is that it revolves around the earth. This is the classic example of how easy it is to form a convincing hypothesis and yet be quite wrong.

Third comes testing the hypothesis by means of further observations. Such testing usually leads to changes in the hypothesis. Sometimes it is necessary to abandon the first hypothesis in favor of a new one. Observations by astronomers eventually led them to abandon the hypothesis that the sun revolves around the earth in favor of the modern hypothesis that the earth rotates on its axis and, together with the other planets, revolves around the sun.

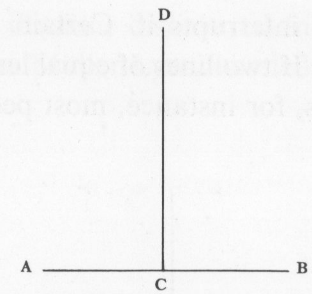
This last hypothesis has been verified by a great many observations, such as the way the other planets wander around the sky in relation to the stars, which remain fixed. So many observations have verified the hypothesis that it has been graduated to the status of a theory. This is the fourth step in the scientific method.

But no hypothesis or theory ever is proved to the point of being unimprovable. The modern theory about the relations among the sun and the earth and other planets is based on the laws of gravitation, but, despite centuries of study, the nature of gravitational force is a mystery. If the mystery is solved, the theory about the sun and the planets may change again.

This should make it easy to understand that visual illusions, the study of which involves that extremely difficult task of observing the relation between what goes on outside a person's skin and what goes on inside it, still are far from being fully understood. Progress has been made, especially in the last couple of decades, but to understand and value that progress one needs to know some of the difficulties involved in making it.

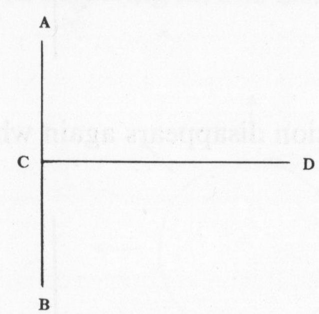
A good example of how difficult it is to conduct scientific studies of visual illusions is provided by the stovepipe-hat illusion, which you saw in the Introduction. Opposite, above, is a simplified version of the figure which causes this illusion.

As you can easily determine with a ruler, the vertical and



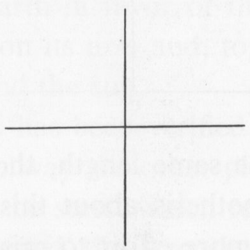
horizontal lines are the same length, though the vertical one looks longer. One hypothesis about this, made several years ago, was that it takes more effort to raise your eyes a certain vertical distance than to move them horizontally the same distance. This did not hold up under investigation. For one thing, it never was possible to show that raising the eyes vertically does require more effort than moving them the same distance horizontally. Neither has it been demonstrated that, if such greater effort were involved in raising the eyes, the effort would make the vertical distance seem greater.

But the best evidence that the hypothesis is wrong came when a research worker turned the figure on its side:

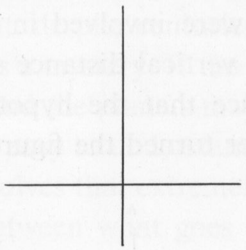


Many people find that the line CD continues to seem longer than line AB.

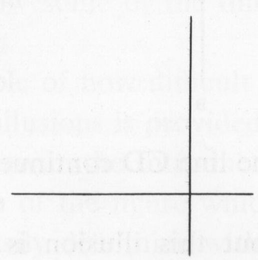
Another hypothesis about this illusion is that AB seems shorter because CD interrupts it. Certain other observations seem to confirm this. If two lines of equal length interrupt each other at their centers, for instance, most people experience no illusion:



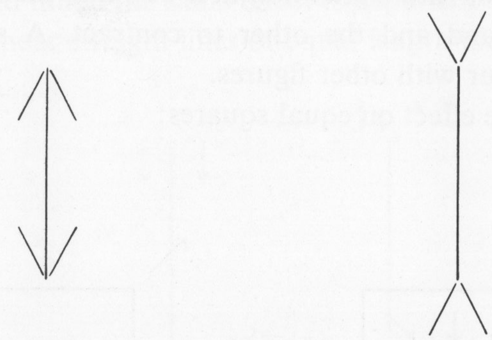
But if the lines interrupt each other unequally, the illusion crops up again—the line with the greater uninterrupted stretch seeming longer than the other:



The illusion disappears again when the interruption again is equalized:

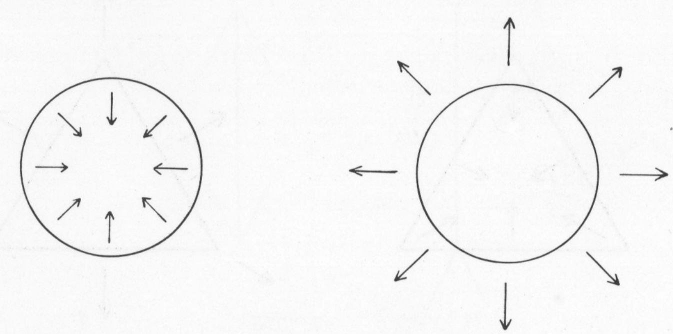


Another visual illusion, discovered in 1889 by a German psychologist, Franz Müller-Lyer, has led to a wide variety of hypotheses:



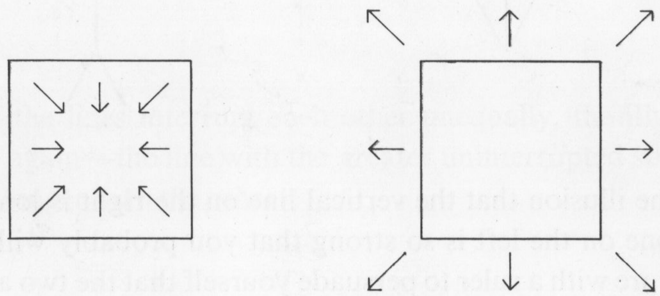
The illusion that the vertical line on the right is longer than the one on the left is so strong that you probably will have to measure with a ruler to persuade yourself that the two are of the same length. Müller-Lyer and other research workers showed drawings like this to many people, all of whom found it hard to believe that the lines were equal.

A number of other illusions involving arrows also have been studied. For example:

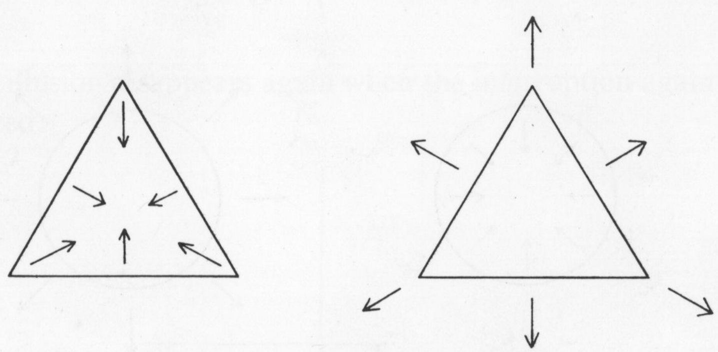


Almost everyone who sees these drawings thinks the circle with the outward-pointing arrows around it is bigger than the one with inward-pointing arrows inside it. One hypothesis is that the arrows direct attention in a way that makes one circle seem to expand and the other to contract. A similar effect seems to occur with other figures.

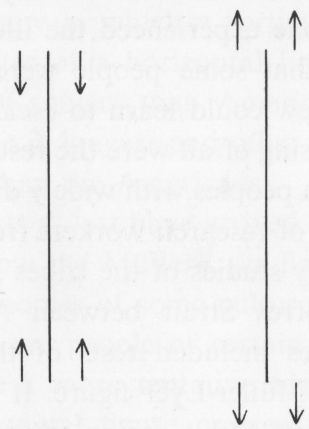
Here is the effect on equal squares:



And here is the effect on equilateral triangles:

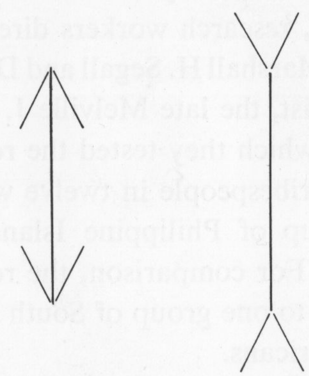


So far, the hypothesis seems supported by the observations. For almost everyone, the figures with outward-directed arrows look larger than the corresponding figures with inward-directed arrows. And much the same effect is experienced when arrows are placed near straight lines of equal length like this:



But this should look familiar. It resembles the Müller-Lyer illusion, though differing from it in one startling particular.

Here is the Müller-Lyer illusion again for comparison:



The Müller-Lyer lines end in arrows, but the effect is exactly the opposite of the one we have been observing. The Müller-Lyer line ending in outward-pointing arrows is the one that seems shorter.

This is by no means the only contradictory evidence involving the Müller-Lyer illusion. As already mentioned, it first seemed that everyone experienced the illusion. But later, investigators found that some people were affected less than others and that a few could learn to escape the illusion altogether. Most surprising of all were the results of the studies of the figure's effect on peoples with widely differing ways of life.

In 1898 a group of research workers from Cambridge University made lengthy studies of the tribes living on the shores and islands of Torres Strait between Australia and New Guinea. The studies included tests of the reactions of the tribespeople to the Müller-Lyer figure. It turned out that the peoples of the Torres Strait region were decidedly less susceptible to the illusion than were the British scientists administering the tests.

More than half a century passed before scientists were able to organize a large-scale study of such difference in susceptibility. In the 1950s, research workers directed by two American psychologists, Marshall H. Segall and Donald T. Campbell, and an anthropologist, the late Melville J. Herskovits, started a six-year study in which they tested the reactions of thirteen groups of African tribespeople in twelve widely scattered villages and one group of Philippine Islands villagers to the Müller-Lyer figure. For comparison, the researchers administered the same tests to one group of South African whites and two groups of Americans.

The results were remarkably like those of the 1898 Torres Strait study. All of the African and Filipino village groups

were less susceptible to the illusion than the South African whites and the Americans. Some of the villagers were affected scarcely at all by the illusion.

The studies also made clear that what was involved was no mere matter of "civilized" people being more subject to illusions than "primitives" are. For the researchers also tested responses to the figure in which a vertical line stretches upward from the center of a horizontal line. Some groups of Africans were more subject than Americans to the illusion that the vertical line is longer, and other groups of Africans were affected less than the Americans.

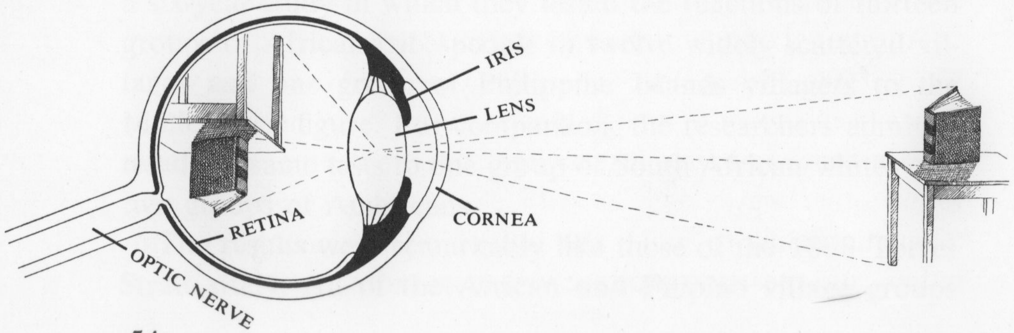
Recently, scientists at last have arrived at a hypothesis that seems to explain how the Müller-Lyer figure creates an illusion and why the peoples of some cultures are affected by it more strongly than are people of certain other cultures. Researchers also have a more tentative hypothesis about how the vertical-on-horizontal figure creates an illusion. But in order to understand these hypotheses it is necessary to know a little more about some other studies of how we see things.

3

On the Track of the Great Guess

As explained earlier, when a person looks at something—say a book lying on a table—light reflected by the book and the table enters his eye. On the back of his eyeball, which is called the retina, this light forms an image that is a miniature representation of the objects reflecting the light. One of the startling things about this image on the retina is that it is upside down.

Here is how this happens:



In the past, some scientists thought that this was evidence for the greatest visual illusion of all, the illusion that the world is right side up. They argued that, since the retinal image is upside down, we must actually see the world so and that we somehow have learned to suppress this "true" vision in order to believe in a right-side-up world.

This hypothesis depends on the assumption that what a person "sees" is the image formed on his retina. But such an assumption means that there must be something in his brain that looks at the image on his retina. If this is so, how does that something in his brain see the image unless it has a retina of its own? And if it has one, what looks at the image on that retina? And so on, *ad infinitum*.

This is a self-contradictory line of reasoning. The modern theory of visual perception avoids it by reducing the retinal image to the status of a mere accidental by-product. It forms only because the retina stops the light that reaches it through the front of the eye.

In the retina are more than one hundred million extremely sensitive nerve cells which react, when light strikes them, by sending nerve impulses to the brain. The modern theory is that the act of seeing takes place in the mind, not in the eye. That act consists of the interactions of nerve impulses from the retina with other nerve impulses produced by the cells of the brain.

Additional observations backing this theory include the way we "see stars" when struck sharply on the head in certain ways. It has been shown that such blows cause retinal nerve cells to release nerve impulses just as light does. Scientists also have found other ways, such as with electric shocks and moving magnetic fields, to make the retinal cells release nerve impulses, and these too produce visual sensations.

Like the theory about how the solar system works, this theory of vision does not explain everything. Science has much to learn about how the brain works, how nerve impulses form and dissolve their patterns, how awareness occurs and fades, what constitutes consciousness and how it can be distinguished from "the unconscious." But one of the most exciting things about the age we live in is that research workers in many fields are making progress toward answering these questions.

One direction of progress is toward answering a question which is the subject of an ancient controversy—namely, does an infant see at birth? Are his retina and brain so organized that they immediately go to work organizing the nerve impulses triggered by light, so that the world around him will make sense? Or does he at first see only a chaos, which he slowly learns to make sense of by separating it into patterns?

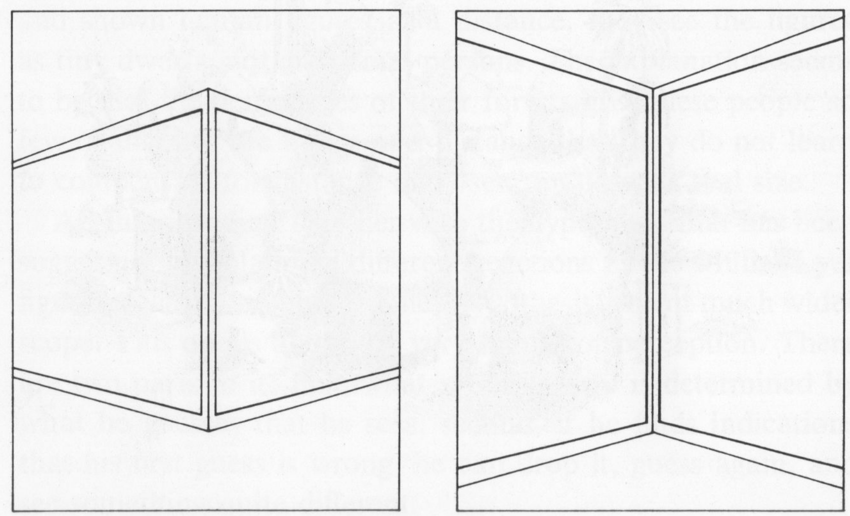
The first possibility is an example of a philosophy called *nativism*; the second possibility represents *empiricism*. Until the last generation it seemed to most interested scientists that they had to choose between these two positions, that the twain could never meet. Indeed, scientists being as prone to strong feelings as any of us, there were times when nativists had trouble speaking civilly to empiricists and vice versa.

But in the last few decades researchers have found evidence that both nativists and empiricists are partly right. A number of ingenious experiments have shown, for instance, that even one-day-old infants do perceive and take interest in visual patterns. One of the simplest and most conclusive of such experiments consists of holding before the eyes of babies different cards, some blank and some with patterns of various kinds. The babies show much more interest in the patterned cards. This makes clear that they are born with at least some degree of ability to respond to visual stimulation by perceiving patterns. Otherwise, they would be equally interested in the blank cards.

But other studies indicate that much of what constitutes seeing has to be learned. Among the most interesting of these studies are ones showing that the tribespeople of the Torres Strait, African, and Filipino cultures were less susceptible to the Müller-Lyer illusion than were the South African whites and the Americans given the same tests.

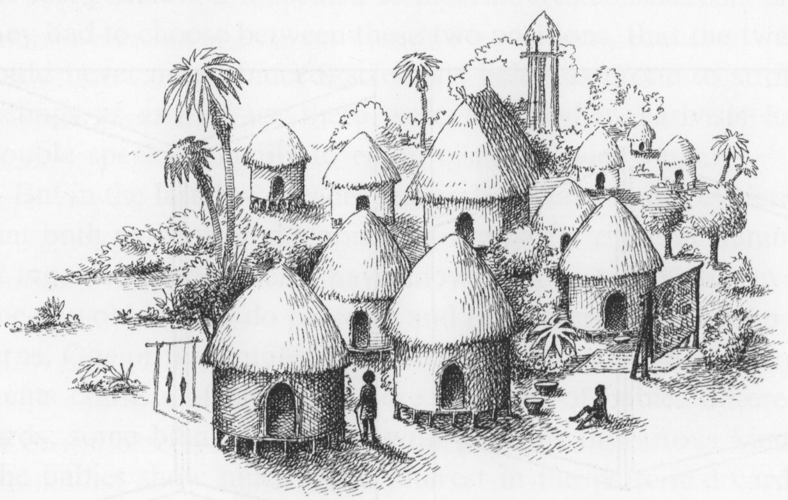
A hypothesis that seems to explain this difference has two parts: South African whites and Americans may be more subject to the illusion because (1) they live surrounded by objects with sharp, right-angled edges, such as houses, boxes and books, and (2) they are used to two-dimensional pictures of such objects that make them seem to have three dimensions.

In other words, to people who have grown up in Western civilization, the Müller-Lyer figures look like drawings of the edges of buildings or boxes or similar objects. For instance:



Just as in the Müller-Lyer figures, the vertical corner lines here are the same length. The corner on the left seems to project toward you and the one on the right seems to recede away from you. We know from experience that our retinal images of receding objects dwindle in size and that retinal images of approaching objects grow. This brings into play the size-constancy habit and, since the two retinal images actually are the same size, causes us to see the receding corner as relatively longer than the approaching one. (Incidentally, unlike the vertical-on-horizontal figure, this one also causes illusion when turned on its side, as you can verify by turning the book.)

According to the hypothesis, the reasons why the members of the Torres Strait, African, and Filipino groups are less subject to the Müller-Lyer illusion are just the reverse. First, their surroundings and possessions include few objects with sharp, right-angled edges. Even their houses usually are round and have doors with curved edges:



Second, the artists in these cultures do not make drawings in perspective.

The hypothesis is new and may eventually undergo a good deal of modification, but results of a number of other studies seem to support it. Among these are studies of how non-Westerners react to drawings done in perspective. For instance, the members of one African tribe, the Yoruba, found it easy to understand such drawings, but most members of another tribe, the Nupe, were confused by them. The explanation seems to be that the Yoruba are used to depth illusion, because their artists are among the few Africans who often create depth illusion in their two-dimensional drawings; but the Nupe artists seldom do so.

A study of people living in dense forest country also seems to support the hypothesis. The results of this study suggest that even the size-constancy habit has to be learned. In such forests the maximum distances at which things can be seen seldom exceed a few yards. When people who have spent all their previous lives in such forests are taken to open country and shown human figures at a distance, they see the figures as tiny dwarfs, not as normal persons. The explanation seems to be that the dense trees of their forests give these people so few chances to see things at a distance that they do not learn to compensate for distance and "see" an object's real size.

All these studies, together with the hypothesis that has been suggested to explain the different reactions of the Müller-Lyer figures, seem to support another hypothesis, one of much wider scope. This one is about the very nature of perception. There are two parts to it: first, what a person sees is determined by what he guesses that he sees; second, if he finds indications that his first guess is wrong, he can drop it, guess again, and see something quite different.

This new and broad hypothesis was suggested by, and has been supported by, a wide variety of observations, and it is highly important in the study of perception. One of the leading research workers in this field was the late Adelbert Ames, Jr., who was a living demonstration that science and art are not always as far apart as is so often asserted. Ames started his professional life as a lawyer, abandoned the practice of law to become a painter, then turned to scientific research on perception. Eventually, he organized and directed the Institute for Associated Research in Hanover, New Hampshire. After his death the line of investigation he started was continued by his former associates, working at Princeton University, and by other scientists working elsewhere.

The simplest experiment involves an observer in a totally dark room. One of his eyes is taped shut, and his head rests in a device which prevents him from moving it. Two points of light then are turned on, both the same distance from his open eye. The only difference between the lights is that one is brighter than the other. But the viewer actually sees the brighter light as being closer than the other.

What could account for this? It cannot be accounted for by the effects of the two lights on the retina. A single, immobile retina can send to the brain nerve impulses registering only the fact that one of the lights is brighter than the other.

(The reason for taping shut one eye and immobilizing the viewer's head is to restrict the experiment to a test of the effects of the two lights on a single, immobile retina. If the subject could use both retinas, each would receive the lights from a slightly different angle, and this would supply clues suggesting that the lights were the same distance from him. If he could move his head, he could receive the lights on a single retina from different angles and pick up the same clues.)

But to get back to what accounts for what the viewer sees in this experiment: *If* the lights actually were of the same brightness and one were closer than the other, then the closer one would deliver to the retina a little more light and thus would be brighter. But this is by no means the only possible explanation for the observed fact that one light is brighter than the other.

One other possibility is the actual case—namely, that the lights are the same distance away but one is brighter than the other. Another possibility is that the dimmer light is very close but very dim and the brighter light very far but very bright. If the test were conducted on a dark night and there were a hole in the end of the room opposite the observer, the bright light might be a star seen through that hole and the dim light an ember only a few feet away.

The hypothesis is that the observer unconsciously chooses one possibility and ignores the others. Indeed, he makes his choice so quickly and with such confidence that the other possibilities do not even occur to him. He literally *sees* that the brighter light is closer and the dimmer one farther away.

(Why he makes this guess rather than some other one is not certain. It may be because a bright light is a potentially greater danger than a dim one. An approaching spark, for instance, grows brighter as it gets closer and more urgently requires evasive action. He who guesses that the worst is about to happen may, in general, have a better chance to survive and guess again. But this aspect of the experiment is not important here.)

This experiment supports the first part of the hypothesis: namely, that what a person sees is determined by what he guesses that he sees. A similar dark-room experiment tests the second part.

In this second experiment the observer is shown two lines of light which are the same height and distance from him but are not the same length. He sees the longer one as closer because he guesses that the lines actually are the same length and that they seem to differ in length only because one is farther away than the other.

But now the viewer is given a stick with a luminous tip and instructed to touch the two lines, one after the other. At first he simply cannot do this. He still is stuck with his guess that they are at different distances from him, and therefore he still sees them that way.

After a few trials, he learns to reach the two lines quite easily. But now he no longer sees them the way he did at first. He sees them as having different lengths but placed at the same distance from him.

This is where the second part of the hypothesis comes in. The subject is not permanently stuck with his first guess. His attempts to reach the lines with the stick provide him new information about the positions of the lines, and this enables him to discard his first guess and make a new one.

These experiments deliberately and drastically simplify the perceiving process, of course. Most of the time there are not just dots or lines of light before our eye but extremely complex and constantly changing scenes. These scenes provide a great variety of clues—such as the distance clues so carefully excluded from the above experiments—so that we are able to make frequent checks on our guesses. We usually do the guessing, checking, and guessing again that make up the process of perceiving quite unconsciously and very rapidly—as fast as thought. That makes the process very difficult to observe.

But Ames found a way of testing perception of more complex scenes too. For this he invented the now famous Ames

Figure 18. Photograph by William Vandivert.

distorted room. Figure 18 is a smaller version of Ames's original room. Photographed from one angle the room looks perfectly normal.

When two faces peer through the windows in the back of the room, appearances no longer are normal (see Figure 19).

Most people seeing this for the first time think that the face on the right looks unnaturally bigger than the one on the left. The new hypothesis explains this. The viewer first makes an unconscious, confident guess that the room has an ordinary

Figure 19. Photograph by William Vandivert.

rectangular shape—with the left corner the same distance away as the right corner and the windows alike in size and shape. But when he examines the faces carefully, he realizes that there is something wrong with his guess.

When we feel this way about something we are looking at, we usually try "to get another angle on it." And that is just what is done in Figure 20.

This provides the data for a new guess—that the room is not the ordinary one it first seemed to be, but is cleverly

Figure 20. Photograph by William Vandivert.

distorted. Instead of being rectangular, it slants off and away to the right in such a way that floor and ceiling are much closer together on right than on left. Also, the window through which the seemingly smaller face is seen actually is much larger as well as closer than the one with the seemingly larger face.

Two American psychologists, S. E. Asch and H. A. Witkin, designed an experiment that tests in a similar way this hypothesis about how we perceive. They built an enclosed room that could be tilted around a subject seated in a chair that does not move. But when the room is tilted, the subject does not perceive that it is tilting. Instead, he "perceives" that he himself is tilting and that the room remains fixed and level.

Our hypothesis predicts that the subject will perceive what he guesses he perceives. In this situation, it is quite appropriate for the subject to guess—and therefore to perceive—that he is tilting and the room is remaining level. For rooms that tilt around chairs that remain stationary are extremely rare creations. None of the subjects of the experiment had had any previous experience of such a room.

But, as our hypothesis also predicts, the subject is not stuck with his guess. If the windows of the room were opened so that the subject seated in the chair could see some of the stable world outside the room—and could thus see that the walls of the room were tilting in relation to that outside world—he could make a new guess. Now he could perceive that the room was tilting while he and his chair remained stable.

Because it predicts the results of these and a great many other experiments, our hypothesis is approaching the status of a theory. And with its help, we at last have a good definition of visual illusions.

4

The Constructive Act of Perception

When so many capable people have tried and failed to define visual illusions, one might think that the reason for failure is that an adequate definition has to be very complicated. Actually, the definition is a remarkably simple one: a visual illusion is a visual perception that proves, when more information becomes available, to need correction.

A simple, logical definition this is. Easy to grasp and hold on to it is not. What makes it slippery is our deeply ingrained habit of feeling that a visual image is a replica, like a photograph, of the scene before our eyes. It takes time and effort to get used to the idea that one's mind is not a blank screen onto which one's eyes focus images.

To recapitulate: What the eyes actually do is translate patterns of light into nerve impulses and send these to the brain. What happens in the instant in which perception occurs can be described, as it was in the last chapter, as making a guess.

Or it can be described as the construction of a visual image.

In the context of the last chapter it was appropriate to call the perceiving process a guess because it usually goes quite rapidly and feels like an instantaneous leap. Here the object is to slow down the process and notice that there are separate steps in it.

The eyes and the brain do not receive images passively. They constitute a system—the visual system—which actively collects information and constructs images.

Ulric Neisser, professor of psychology at Cornell University and one of the leading students of perception, vividly described the role of the eyes in an article in the September 1968 issue of *Scientific American:* "Although the eyes have been called the windows of the soul, they are not so much peepholes as entry ports, supplying raw material for the constructive activity of the visual system."

In addition to the raw material supplied by the eyes, a great deal of information stored in the brain also goes into this constructive activity. For instance, as we saw earlier, the stored information that a person does not change in size as he moves away leads us to see him as remaining the same size at different distances. But in order to make drawings in perspective it is necessary to store in one's mind information about how to make the images of persons and objects different in size when they are to be shown at different distances. And we will see later that we can go on all our lives improving our ability to construct visual images—that is, to see—by continually adding to the store of information we can use in such construction.

When a visual image is thought of not as a simple automatic copy but as a complex construction, it becomes obvious that mistakes are bound to occur, just as they do in constructing houses or anything else. Such mistakes can be classified in different categories. An example of the simplest kind:

A person glimpses in a crowd of people the back of a head. He "perceives" that it is the head of someone he knows, which is to say that he constructs a mental image of the head of the person he knows. But now the head in the crowd turns so that he can see the profile. He now "perceives" that it is the head of a stranger, which is to say that he discards the first constructed visual image in favor of a new one.

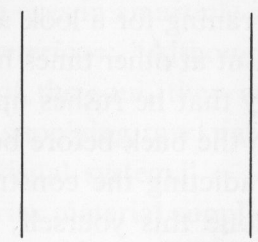
In cases like this a person sometimes is aware that his first visual image is a guess. With such awareness he deliberately seeks more evidence, craning for a look at the profile or some other additional clue. But at other times he may make his construction so confidently that he rushes up to the stranger and starts pounding him on the back before becoming able to take in new evidence contradicting the construction.

If you ever have done this yourself, you may remember telling the story to someone later and using an expression such as "I was *bound and determined* it was so-and-so." This is a revealing expression. It demonstrates one very important characteristic of visual images: the degree of confidence with which one builds such an image determines how convincing it is—no matter how flimsy or inadequate the building materials may be.

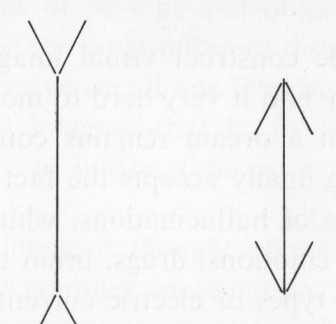
Sometimes people construct visual images with so much confidence that they find it very hard to modify them. This is what happens when a dream remains convincing after one wakes up, until one finally accepts the fact that it is "only a dream." In the case of hallucinations, which may be associated with powerful emotions, drugs, brain tumors, or the application of certain types of electric currents to certain parts of the brain, sometimes no kind of new and conflicting information can persuade the victim to give up or alter his original visual image.

The kinds of visual illusions we are primarily concerned with in this book come between the extremes of easily corrected mistakes on one hand and hallucinations on the other. One kind occurs when the information available enables a person to construct different and contradictory visual images of something he looks at. The Müller-Lyer figure is typical.

When a person looks at two lines of equal length on a flat surface, he has no trouble constructing an image in which the lengths are the same:



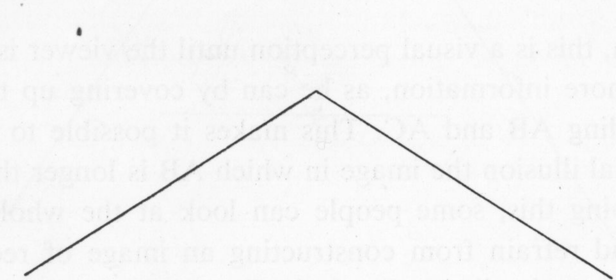
But adding slanting lines to the tops and bottoms of these vertical lines makes those of us who are used to seeing rectangular objects and drawings in perspective construct a quite different visual image. In this one we make the vertical lines the edges of vague, three-dimensional objects:



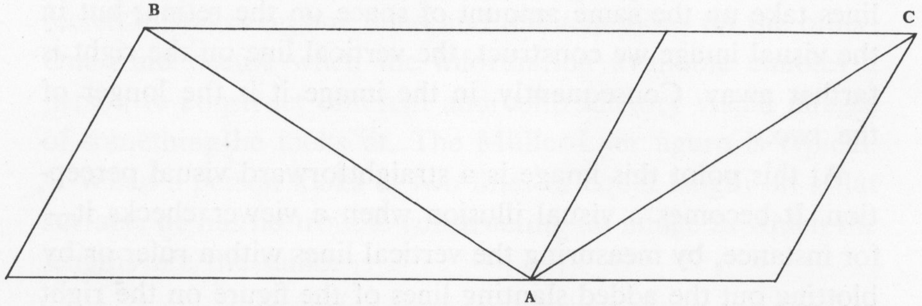
We make the vertical line on the left an edge projecting toward us and the one on the right an edge projecting away from us. This makes it seem that the one on the left is closer. Here the size-constancy habit takes over. The two vertical lines take up the same amount of space on the retina; but in the visual image we construct, the vertical line on the right is farther away. Consequently, in the image it is the longer of the two.

At this point this image is a straightforward visual perception. It becomes a visual illusion when a viewer checks it—for instance, by measuring the vertical lines with a ruler or by blotting out the added slanting lines of the figure on the right by placing something over them. This makes it possible for some people to take another look at the whole figure and construct a new image in which the vertical lines are of the same length. But other people have great difficulty in doing this, apparently because they are "bound and determined" that the first image is accurate.

Here are another pair of lines on a flat surface. Again it is easy to construct a visual image in which the lines' lengths are the same:



But add certain lines, and most people who grow up in our culture construct a quite different image:



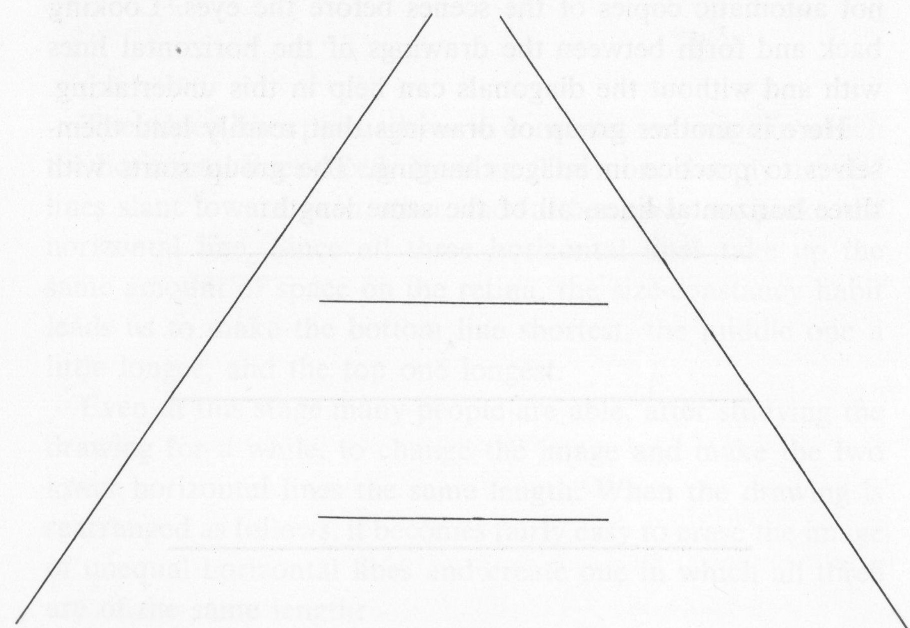
Now, we Westerners find it extremely difficult to construct a visual image in which the line AB is the same length as the line AC. Instead, we construct an image in which these adjacent parallelograms are rectangles receding into the distance. In this image the rectangle on the left recedes farther than the one on the right. Consequently, the diagonal of the left rectangle, AB, is longer than the diagonal of the right rectangle, AC.

Again, this is a visual perception until the viewer is able to obtain more information, as he can by covering up the lines surrounding AB and AC. This makes it possible to identify as a visual illusion the image in which AB is longer than AC. After doing this, some people can look at the whole figure again and refrain from constructing an image of rectangles receding into the distance and of AB as longer than AC. Other people have great difficulty doing this even after they have covered up the extra lines several times.

The drawings involving the two posts, shown on pages

9–10 in the Introduction, work similarly. Here is a simplified version of it that starts with two lines of equal length:

There is nothing about this drawing that would lead us to construct a visual image of anything but two lines of equal length, one above the other. But when converging diagonal lines are added, we construct a completely different image:

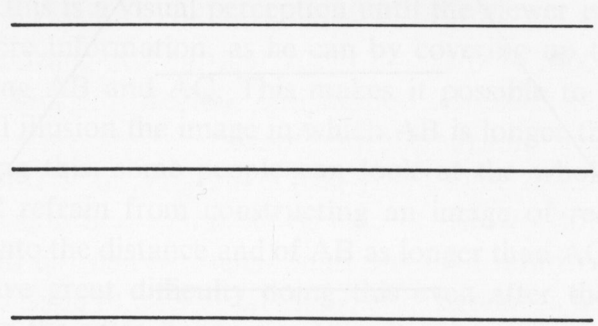


The diagonal lines persuade us to construct an image in which they and the space between them recede into the distance. In this image the upper horizontal line is farther away than the lower one, but the two take up the same amount of space on the retina. This invokes the size-constancy habit and leads us to make the upper line not only farther away but also longer than the lower one.

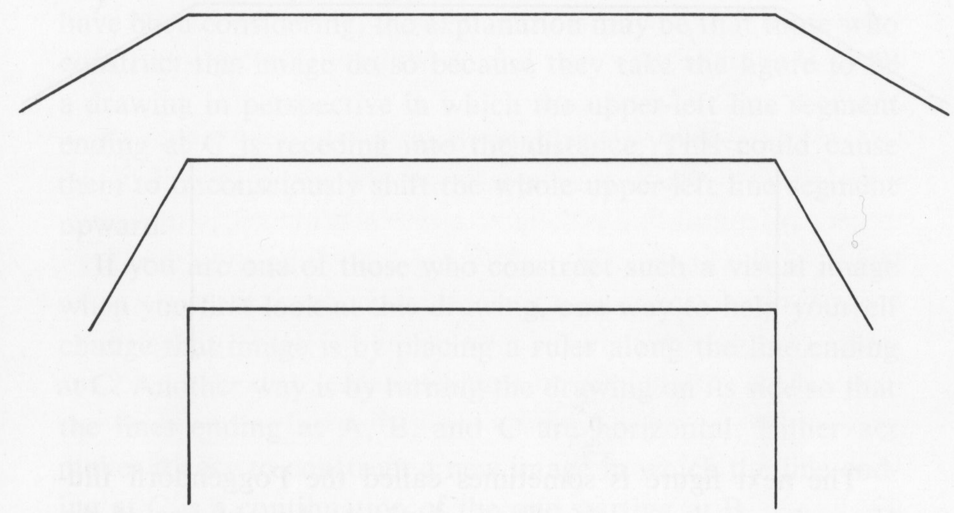
One of the interesting things about this drawing is that some people find it fairly easy to change the image in which the upper horizontal line is longer to one in which it is the same length as the lower, without placing something over the diagonals. At least, they find it easier than changing the first visual image they construct in the case of the Müller-Lyer figure.

It can be very helpful to work at making this change. One needs the experience of consciously changing a visual image in order to fully grasp that perceptions are constructions and not automatic copies of the scenes before the eyes. Looking back and forth between the drawings of the horizontal lines with and without the diagonals can help in this undertaking.

Here is another group of drawings that readily lend themselves to practice in image changing. The group starts with three horizontal lines, all of the same length:

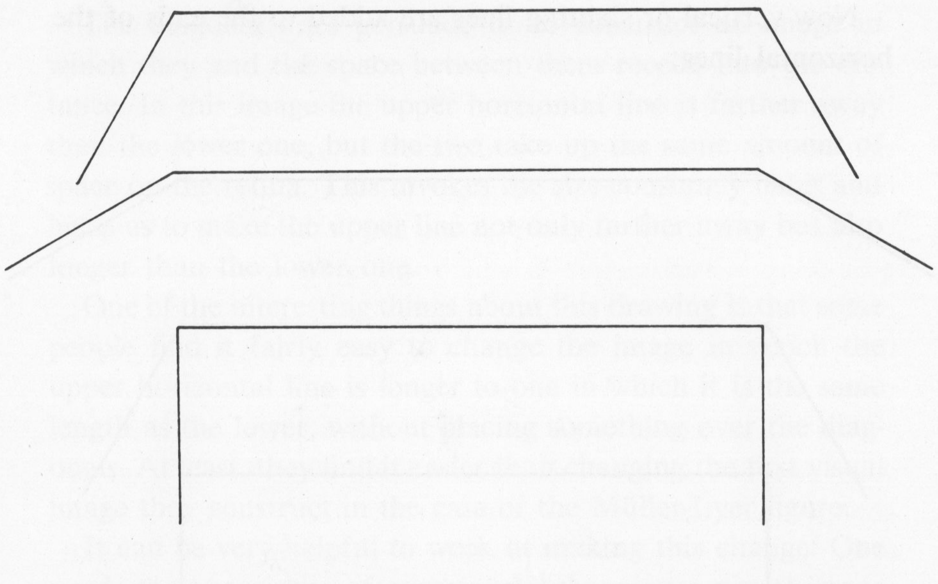


Now vertical or slanting lines are added to the ends of the horizontal lines:

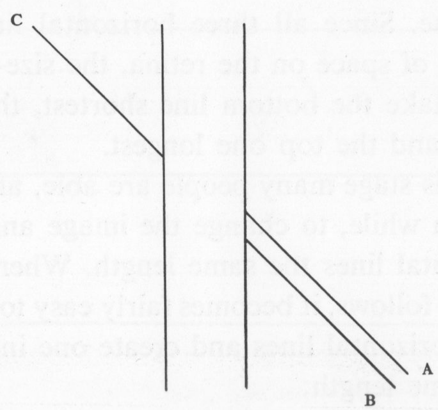


The added lines persuade us to construct an image in which the horizontal lines recede from us. The more sharply the end lines slant toward each other, the farther away we make the horizontal line. Since all three horizontal lines take up the same amount of space on the retina, the size-constancy habit leads us to make the bottom line shortest, the middle one a little longer, and the top one longest.

Even at this stage many people are able, after studying the drawing for a while, to change the image and make the two lower horizontal lines the same length. When the drawing is rearranged as follows, it becomes fairly easy to erase the image of unequal horizontal lines and create one in which all three are of the same length:



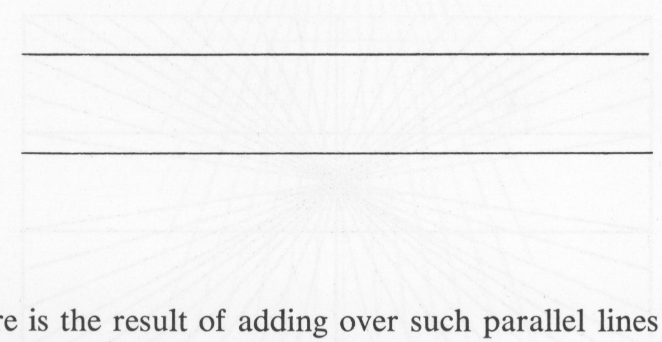
The next figure is sometimes called the Poggendorff illusion, after a nineteenth-century physicist who was one of the first people to study the figure's effect. It also helps make it possible for many people to experience making a conscious change in a mental image:



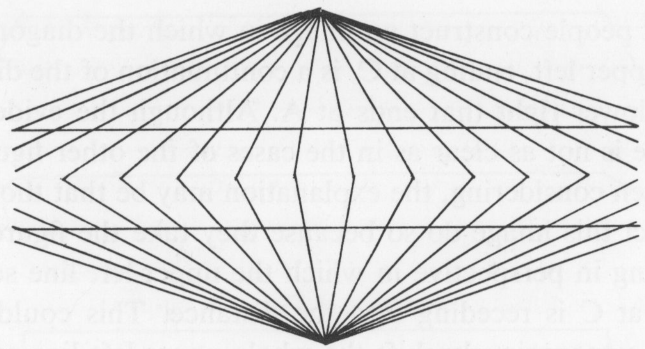
Most people construct an image in which the diagonal line at the upper left, ending at C, is a continuation of the diagonal line at lower right that ends at A. Although the evidence in this case is not as clear as in the cases of the other figures we have been considering, the explanation may be that those who construct this image do so because they take the figure to be a drawing in perspective in which the upper-left line segment ending at C is receding into the distance. This could cause them to unconsciously shift the whole upper-left line segment upward.

If you are one of those who construct such a visual image when you first look at this drawing, one way to help yourself change that image is by placing a ruler along the line ending at C. Another way is by turning the drawing on its side so that the lines ending at A, B, and C are horizontal. Either act makes it easy to construct a new image in which the line ending at C is a continuation of the one starting at B.

More difficult to alter are the mental images that most people who are used to drawings in perspective construct in response to certain figures involving parallel lines like these:

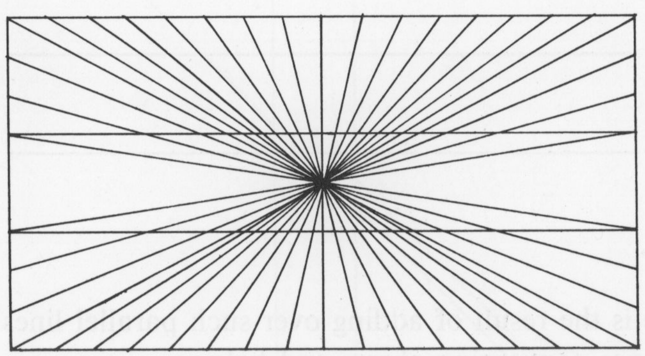


Here is the result of adding over such parallel lines sets of other lines converging above and below:



Most of us now unconsciously construct a visual image of a figure which bulges toward us in the center and away from us above, below, and at the sides. In this image the horizontal lines are on the surface of the figure, so that they too bulge toward us and each other in the center and away from us and from each other at the sides. Even blotting out all the drawing above and below the horizontal lines does not make it easy to change this image into one in which the lines are parallel.

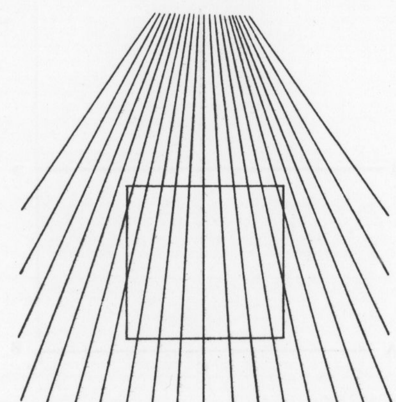
And here is the result of adding a set of lines converging in the center:



Now we unconsciously construct an image of a figure receding toward the point where the converging lines meet. Again, in the image the horizontal lines are on the surface of the figure. As a result, they are closer together at the sides and farther apart nearer the point where the converging lines meet. Many find it extremely difficult to change this image without blotting out all the converging lines.

Indeed, in the cases of these last two figures involving converging lines, some people find it difficult even to realize that they have constructed images of three-dimensional forms. To them the way the parallel lines diverge is an inexplicable mystery.

Here is a somewhat simpler drawing of the same kind. This one makes it easier to catch oneself constructing an image of a figure receding into the distance and to change that image. It also helps to make clearer the relationship between these drawings involving many converging lines and the one on page 73 involving only two converging lines.

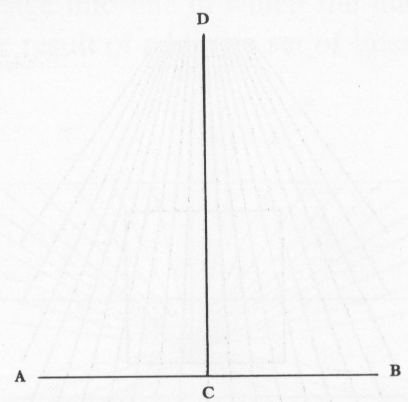


This causes most of us to construct an image in which the converging lines recede into the distance. And the four-sided figure recedes with them, its bottom line being closer and its top line farther away and a little longer than the bottom one. Its side lines diverge from each other as they recede.

But now arrange strips of paper or other objects around the four-sided figure so that they obscure the converging lines at the top, bottom, and sides. This should enable you to discard your first image and make a new one in which the four-sided figure is a square.

All of these drawings are related to the Müller-Lyer figure, because like it they involve constructing three-dimensional visual images. Just what is involved in the vertical-on-horizontal figure is not so clear. As mentioned in Chapter 2, some people who grow up in cultures different from ours are more susceptible to the illusion caused by this figure, and some are less susceptible.

Here is the figure again:

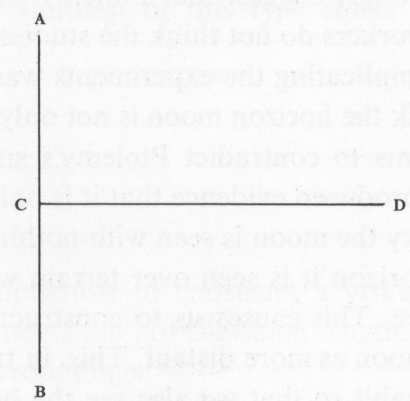


At first it seems reasonable to think that this might have an effect similar to that of the Müller-Lyer figure. According to

this reasoning, the drawing causes us who are used to drawings in perspective to construct a visual image in which the line CD recedes into the distance while the line AB remains nearby. This brings into action the size-constancy habit and causes us to make CD the longer of the two.

Studies of the drawing's effect on people of other cultures seem to back this hypothesis. People least subject to the illusion that CD is longer are those who live in dense forests and are least subject to the size-constancy habit. People even more subject to the illusion than people of Western civilization are those who live in wide open deserts and savannas, are constantly exposed to long-distance views, and seem to be even more strongly committed than we are to the size-constancy habit.

So far, so good. But, as also was mentioned in Chapter 2, there are many people who still construct visual images in which CD is longer than AB when the figure is turned on its side:



This makes it seem possible that other factors are involved. It has been suggested that the way the lines interrupt each other may be such a factor. But if this is so, there still are many details to work out concerning how this affects the visual images we construct and how it fits with the evidence of different reactions among peoples with different backgrounds.

Another famous visual illusion for which there have been differing explanations involves the full moon. When it first clears the horizon, most people perceive the full moon as much bigger than when it is high in the sky. This does not seem to be due to any bending of the light rays by the atmosphere or to other phenomena independent of the mind of the perceiver. The moon's image on the retina, or in a photograph, is the same size at the zenith as at the horizon.

In the second century A.D. the great Alexandrian astronomer Ptolemy speculated that the horizon moon looks bigger because it is perceived as farther away than the high-in-the-sky moon. Over the centuries many other hypotheses were proposed. In 1956 two young American psychologists, Lloyd Kaufman and Irvin Rock, began a series of complex experiments which strongly suggest that Ptolemy was right, though some research workers do not think the studies are conclusive.

One thing complicating the experiments was that most people say they think the horizon moon is not only bigger but also closer. This seems to contradict Ptolemy's suggestion. Kaufman and Rock produced evidence that it is only an aftereffect.

High in the sky the moon is seen with nothing else intervening. Near the horizon it is seen over terrain which creates an effect of distance. This causes us to construct a visual image of the horizon moon as more distant. This, in turn, invokes the size-constancy habit so that we also see the horizon moon as larger. Because the size-constancy habit operates unconsciously, we can consciously reason that the horizon moon is larger because it is closer in spite of having constructed an image in

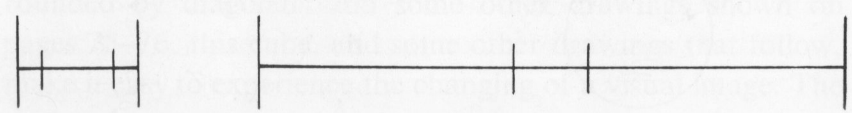
which it is larger because it is farther away.

In one of the most clear-cut of the two psychologists' many experiments, the subjects were asked to look at the horizon moon in the ordinary way. As usual, they reported that it looked larger—i.e., they reported that the image of the zenith moon shown them on a screen at the same time had to be magnified in order to seem as large as the horizon moon. But when the experimenters blotted out the terrain surrounding the horizon moon, the subjects reported that it looked the same size as the zenith moon.

Incidentally, some people have the impression that the horizon moon looks larger because we can compare it with objects which we see next to it and which we know are large —objects like houses and trees. This is mistaken, because the horizon moon looks just as big when seen over water or desert where there are no objects for comparison. However, there are certain types of drawings which do cause illusion effects by means of comparisons.

One of the simplest of this type starts with segments of straight lines:

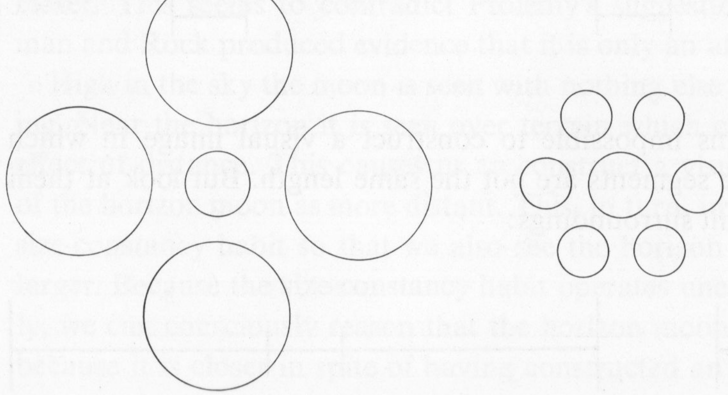
It seems impossible to construct a visual image in which these line segments are not the same length. But look at them in different surroundings:



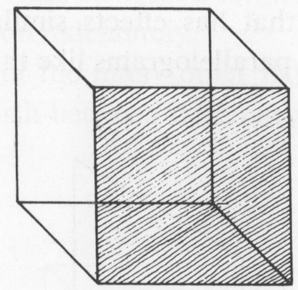
Now it is difficult to construct an image in which the line segments still are the same length. This apparently is because the one on the left is so much bigger than the line segments surrounding it that we associate it with the idea "big," while the one on the left is so much smaller than its companions that we associate it with the idea "small." These associations strongly influence the lengths of the line segments in the images we construct.

A similar effect can be created with circles. It is quite natural to construct an image in which these two circles are of the same size:

But when these same circles are surrounded as in the following drawing, it becomes almost impossible to construct images in which their sizes are the same:



Another type of drawing causes most people to construct one visual image, then erase it and construct a second, then return to the first, and so on indefinitely. This cube is an example:

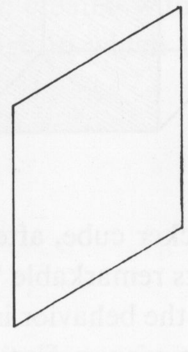


This is called the Necker cube, after L. A. Necker, a Swiss naturalist who noticed its remarkable "behavior" in 1832. The quotes are used because the behavior is ours, not the drawing's. What happens is that a viewer first constructs an image in which the tinted area is an outer surface of a transparent box. Then, if he continues to look at the figure, he erases that image and constructs a new one in which the tinted area is an inner surface of a transparent box tilted differently from the first one. And as long as he keeps on looking, he switches back and forth between these images every few moments.

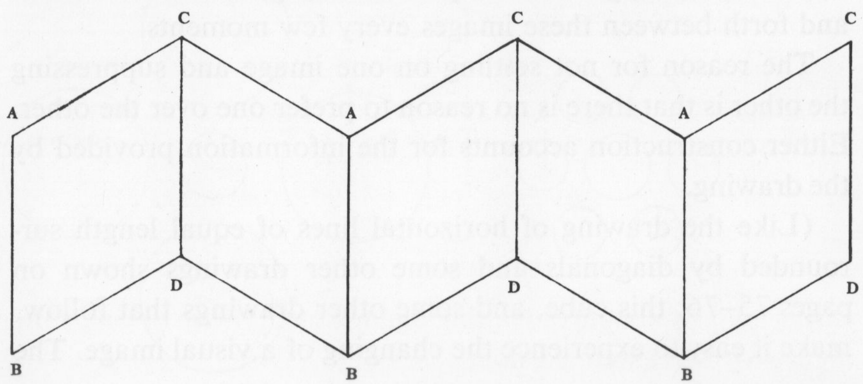
The reason for not settling on one image and suppressing the other is that there is no reason to prefer one over the other. Either construction accounts for the information provided by the drawing.

(Like the drawing of horizontal lines of equal length surrounded by diagonals and some other drawings shown on pages 75–76, this cube, and some other drawings that follow, make it easy to experience the changing of a visual image. The difference is that in these latter cases the changes come much more easily—in fact, involuntarily. Still, by noticing that the images or perceptions do change, one can gain additional insight into their status as active constructions rather than passive copies.)

Another drawing that has effects similar to those of the Necker cube involves parallelograms like this one:

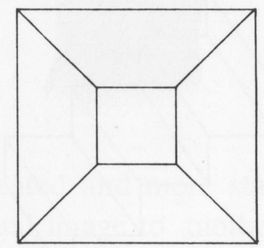


As mentioned in connection with an earlier example, we Westerners are stimulated by a figure like this to construct an image of a rectangle receding into the distance. But link together a series of such parallelograms and behold:

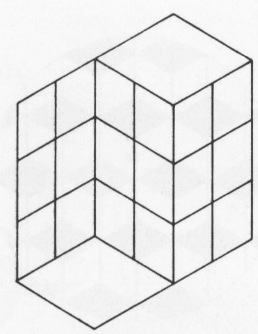


Now we construct an image of an unfolded screen which not only has three dimensions but also zigzags toward us and away from us. At one moment the lines marked AB push forward. Then they recede and the CD lines push forward. And since the figure provides no reason for preferring either image, this switching goes on indefinitely.

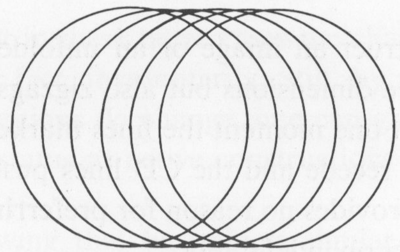
Here are a few of the many other figures that cause us to switch back and forth between different visual images:



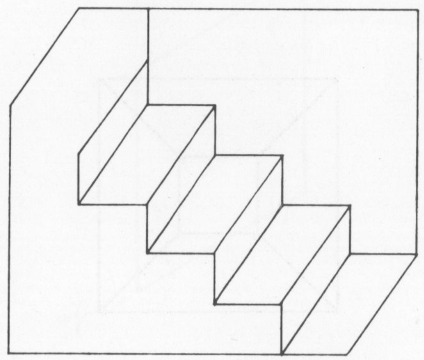
Either receding or protruding;



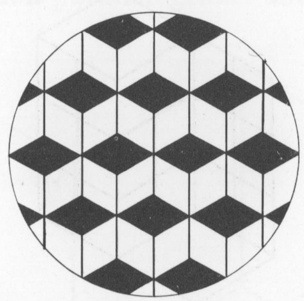
either two solid figures leaning against each other or one solid figure with an extended side;



a hollow tube running either from left to right or from right to left;

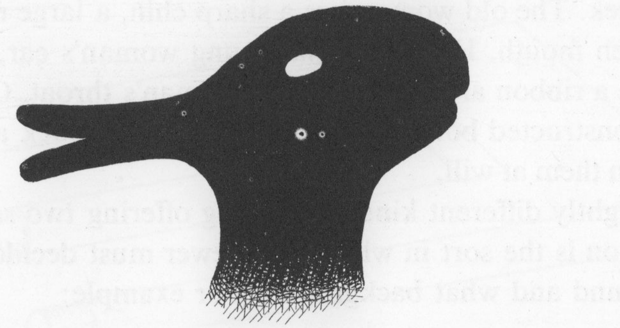


either a staircase or an overhanging cornice.



The dark areas can be either the top of one set of cubes or the bottom of another set.

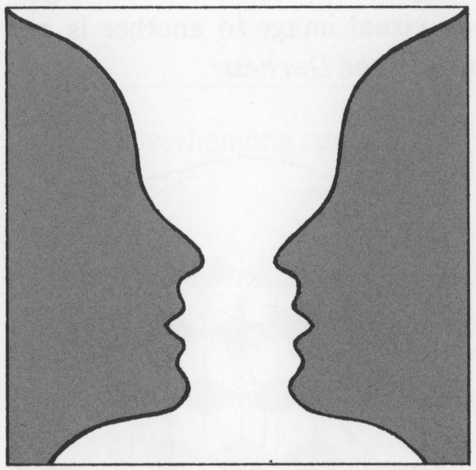
It is not only with geometrical figures that this sort of thing happens. Complex drawings depicting familiar things also can present contradictory information, causing us to construct first one image and then another quite different one. One of the oldest and best-known examples is the duck-or-rabbit drawing:



Still more complicated and more startling when you first switch from one visual image to another is a drawing sometimes called *Daisy or the Duchess:*

A psychologist who tried this on his students reported that sixty percent of them first were stimulated to construct an image of a young woman, forty percent that of an old woman. If you need hints, the young woman is looking off and a little up to the left with her head turned away so that only her long eyelashes and the tip of her nose show beyond the curve of her cheek. The old woman has a sharp chin, a large nose, and a sunken mouth. Her eye is the young woman's ear, and her lips are a ribbon around the young woman's throat. Once you have constructed both images, you can switch back and forth between them at will.

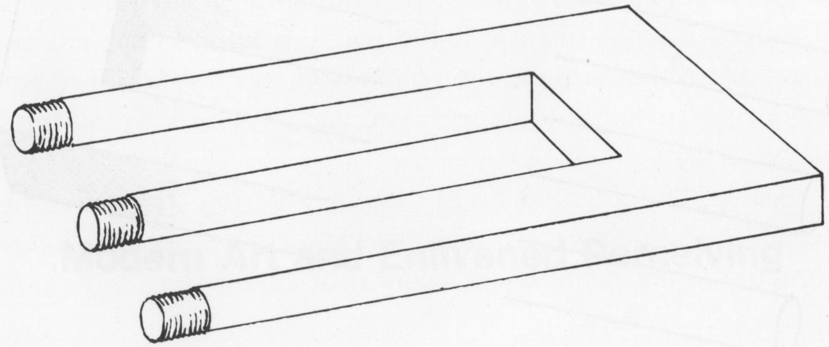
A slightly different kind of drawing offering two sets of information is the sort in which the viewer must decide what is foreground and what background. For example:



If you take the white space to be the foreground, you construct a visual image of a wide-topped vase. If you take the

gray space as the foreground, you construct an image of two human profiles facing each other.

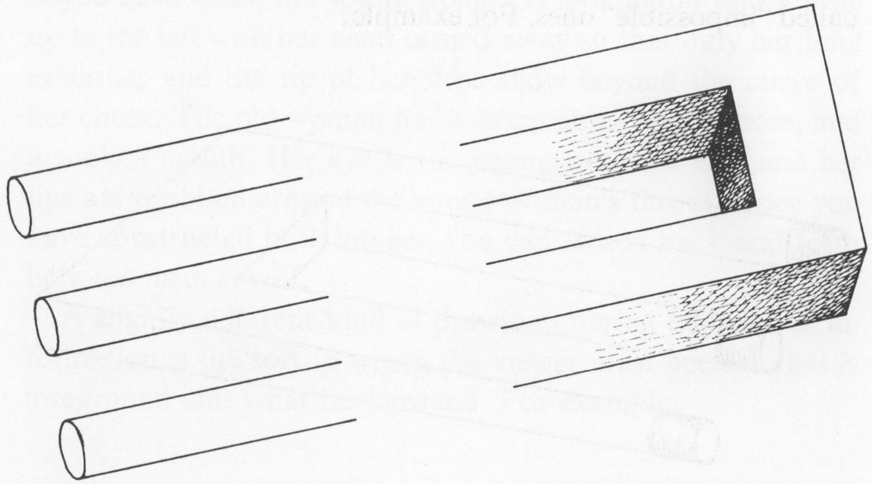
But the most interesting drawings of this sort are the so-called "impossible" ones. For example:



Many people report that looking at this figure for any length of time makes them feel uncomfortable, in some cases even dizzy. There is, obviously, an important difference between this drawing and the others we have been considering.

In the case of the vase-or-profiles drawing, for instance, one can make a choice between two sets of information. One can concentrate on the set of information that makes it possible to construct a visual image of a white vase against a gray background. Or one can concentrate on the set that makes it possible to construct an image of gray profiles facing each other across a white background. What makes the new drawing "impossible" is that the two contradictory sets of information are so thoroughly blended with each other that it is difficult to separate them and attend to one while ignoring the other.

Difficult, yes, but not really impossible. Here are the two separate sets of information:



Indeed, you can separate the two sets of information simply by placing a finger first across one end of the original drawing, then across the other end. And if you find that the figure still bothers you when you look at it, try drawing a duplicate of it. Such efforts make it possible for many people to get used to the figure little by little and, eventually, to look at it without discomfort.

Trying to accustom yourself to this figure, and the various ways suggested earlier of approaching other figures that cause visual illusions, can help you educate your visual system. For sources of even more effective help we now return to art, and to modern art in particular.

5

Modern Art and Enlivened Perceiving

Why should anyone want to look at a work by the kind of painter who refuses to paint things "the way they really look," unless the viewer happens to like the painting at first glance? There are two good reasons: in order to learn to enjoy the painting, and in order to learn to see better.

To anyone unused to the idea of making an effort to enjoy something, the first reason may sound self-contradictory. Actually, effortless pleasure is pallid to start with and quickly ends in boredom. Even a traditional masterpiece, such as a painting by Rembrandt or Michelangelo, soon bores anyone who looks at it passively, even though he may be quite sure that he "likes" it.

In response to such paintings it is easy to construct simple, familiar visual images, and the ease of doing so is what makes them readily, if briefly, attractive. Many works of modern artists, on the other hand, challenge the viewer immediately.

They make it extremely difficult, if not impossible, for him to construct simple, familiar visual images. He has to make an effort to respond at all. If he does respond, and not simply turn away in defeat, he usually winds up constructing new and different visual images, sometimes several of them in response to the same painting. This is exciting.

It also is instructive, which is the second reason for putting effort into looking at such paintings. Effort invested in looking at traditional masterpieces can get to be exciting and instructive because the viewer eventually finds that it is possible to construct, in response to these works, visual images much more complex than the first simple, familiar ones. But for many people it is easier to get started on this enterprise by looking long and hard at paintings which evoke nothing simple and familiar in response.

The dark-room experiment with the two dots of light helps make clear why this is so. In that experiment the subjects almost instantly constructed a visual image in which the dim light was farther away and the bright one closer. This was only one of many visual images that could have been constructed to account for the information, but the subjects did not try to construct any others, because they were satisfied with the one they had. It is all too easy to be similarly satisfied with the first visual image one constructs in response to traditional paintings.

In daily life too we usually construct our visual images the way the subjects of this experiment did—quickly and finally. It may seem that there is no harm in this except for occasional, easily correctable mistakes such as when we "recognize" the back of the head of a stranger in a crowd. But it means we make only shallow use of our visual systems.

The amount of raw material in the light reaching a person's

eyes is enormous. And there is no known limit to the amount of information that can be stored in the human brain and used, in conjunction with that raw material, in the constructive activity of the visual system. To be satisfied with the first quick, easy visual image that can be constructed—to be "bound and determined" that it is the only possible image—is to wear self-imposed blinders and filters.

How many times, for instance, have you suddenly realized that you had failed to see something that was "right in front of my eyes all along"? This happens frequently to many people. And for every such occasion there probably are dozens of others when one never does come to realize that one has failed to see something well within range because one has unthinkingly accepted as final a visual image constructed in great haste.

Making do with hastily constructed visual images is only a habit, and habits can be weakened or even broken. Never before in history has so much help been available to those who want to break this one. In the days of Giotto, painters began learning to break themselves of the size-constancy habit. In the days of Cézanne they began learning to break the habit of constructing only visual images with everything in perspective. Today they are free to and able to construct almost endlessly varied kinds of visual images.

But many of the resultant paintings, it might be objected, resemble nothing ever before seen on earth. They are wholly imaginary. How can they help anyone use his visual system to better perceive the real world around him?

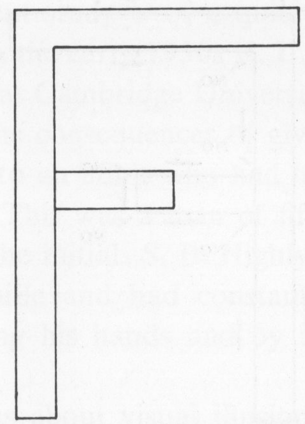
This is where the results of scientific study of visual illusions come in. Those studies show that many of the figures causing these illusions do so because of what we imagine we see in the figures. Other experiments, such as the dark-room ones with the two dots and the two lines of light, also demonstrate a connection between what we imagine and what we perceive. And before going into specific ways in which specific works of modern art can help a person see better, let us consider three more scientific studies which approach the subject of visual perception from two new directions, both different from the approaches we have considered so far.

The first was suggested by Julian Hochberg of New York University and is a demonstration you can do for yourself. Simply try to remember how many windows there are in your home. Unless by coincidence you have counted recently, you probably cannot do this without seeing the sides of the building, either from the inside or from the outside. But if you are like most people, you will not have to have the building before your eyes. Instead, you will be able to imagine each wall in turn and count the windows in these imagined representations.

What this demonstrates is that you can learn from an imagined scene as well as from one actually before your eyes. In this case you learn from an imagined scene the number of rooms in your home. The experiment also provides one more bit of evidence in support of the hypothesis that to see something and to imagine it involve closely similar processes, if not the very same process.

The second study approaches the subject in the same way but is much more elaborate. It is one of several similar studies devised by Lee R. Brooks of McMaster University in Hamilton, Ontario. He first showed his subjects a large block-letter *F*, as shown opposite.

He asked them to remember what this looked like, then hid it from them. Next he asked them to imagine the letter and to categorize each of its corner points by assigning a "yes" to each corner point at the top or bottom of the figure and a

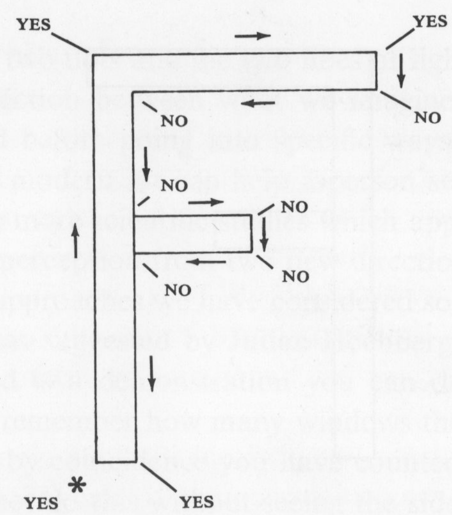


"no" to each corner point in between as shown in the figure on page 98.

There are, you can see, ten corner points on the letter. If you start at the lower-left corner point indicated by the asterisk and proceed around the letter in the direction indicated by the arrows, you will produce the sequence "yes, yes, yes, no, no, no, no, no, no, yes."

Sometimes the subjects were asked simply to *say* "yes" or "no" while visualizing the points one after another in their trips around the imagined letter. At other times they were asked to *point* to a printed "yes" or "no" while performing the task of categorizing the corner points in the imagined letter. (Subjects never knew in advance at which point they would be asked to start their trips around the letter, so they could not simply memorize a sequence of yeses and noes. Various other safeguards we need not go into here also were used to make sure that all subjects approached their respective tasks in the same way.)

It took the subjects an average of just a little more than eleven seconds to make their trips around the letter when they



were allowed to say "yes" or "no." It took them an average of twenty-eight seconds when they were required to point to a printed "yes" or "no."

To understand what this has to do with our hypothesis that perceiving and imagining are closely similar processes, consider how it would be to go through these two routines if you were actually looking at the printed letter. It would be very easy to say "yes" or "no" when looking at the appropriate spot on the letter. But if you had to look at the spot on the letter and then look elsewhere for printed yeses and noes to point to, you would spend more time on the task, because each response would take two separate glances.

What the Brooks experiment demonstrated was that his subjects treated the imagined letter just as they would a letter present before their eyes. In other words, here is more strong evidence that imagining something involves the same process as perceiving it. In both cases, it seems, we construct visual images.

The third pertinent study is of a quite different kind and had a sad ending. In the early 1950s R. L. Gregory and J. G. Wallace, both then at Cambridge University, were able to investigate in detail the consequences of giving sight by means of corneal grafting to an adult who had been blind from the age of ten months. This was a man of fifty-two identified in the report only by the initials S. B. Highly intelligent, he had read widely in Braille and had constantly explored things around him by using his hands and by asking questions of sighted people.

As our hypothesis about visual illusions would predict in such a case, he was not susceptible to the Müller-Lyer, Poggendorff or other standard illusions when he gained his sight, nor could he accurately judge depth and distance. But the most interesting findings concern what he could learn to see, what he could not learn to see, and what he could not bear to see.

As soon as the bandages were removed from his eyes after the operation, S. B.'s new corneas admitted to his retinas as much light as a person sighted from birth needs for seeing quite clearly. His physician spoke to him. S. B. knew the voice well and could focus on the spot from which it came. But when he had done so, he saw no lips or face. He saw only a blur.

Over a period of several weeks, he gradually learned to see faces in the sense of distinguishing among the various features and noticing differences between those of different people. But they always remained difficult, and frequently were confusing, for him to look at. And although he could accurately judge a person's feelings from tones of voice, he never learned to make anything of facial expressions. He never learned, that is, to construct visual images of faces that had enough detail to tell him whether the features were set in a sneer, for instance, or in a smile.

On the other hand, he quickly learned to tell time from a large wall clock, and to recognize cars, trucks, and buses. On his first trip to the zoo he was able to name most of the animals at first sight. The reasons for these successes seem clear. For many years he had carried an unglassed watch so that he could tell time by feeling the positions of the hands. He also had delighted in exploring toy machines and toy animals as well as full-sized machines and pet animals with his hands and had asked members of his family and friends endless questions about the appearance of such objects. In other words, he had stored a great deal of information about these objects which he was able to learn to combine with the raw material provided by his eyes. In the case of facial expressions he had no stored information; they were as strange to him as they are to an infant.

But the saddest part, and here one of the most important, of S. B.'s story concerns what he could not bear to see. He liked only bright colors and bright daylight, could not bear blemishes or flaking paint, and tended to become depressed when daylight faded. His depression gradually deepened, and he lost interest in using his eyes, preferring to sit in darkness rather than turn on a light. Within three years he died.

Profound depression like this is common among people who regain their sight after many years of blindness. Many patients end by refusing to use their eyes at all, after a period of trying. They find the world's visible imperfections unbearable. They also come to realize that they can never make up for the lost years of experience in using their eyes. They have forced on them the knowledge, hidden from those sighted from birth, that only years of practice make it possible for

anyone to see—i.e., to construct visual images of—much of what goes on around him.

To recapitulate what the experience of these people demonstrates:

First, what the eyes supply is only raw material. The visual system also needs a large backlog of stored information in order to make use of that raw material in constructing visual images.

Second, it is possible to fall into the habit of wanting to create only certain types of visual images, such as S. B.'s bright, blemish-free ones.

Third, that habit can lead to refusal to use the visual system if the raw material or information available seems to be leading to construction of unwanted visual images.

To sum it up another way, a person can go on learning to see better and better all his life, but he also can refuse to learn to see better. One of the commonest forms this refusal takes is the refusal to put effort into looking at the work of new and original painters. This is a rejection of one of the best sources of help in learning to see better, a rejection summed up in the cliché "I don't know anything about art, but I know what I like."

Only rarely can a truly original idea result in an easily likable painting. Most great innovations in painting provoke uneasiness, if not outright hatred and ridicule, when they first appear. This probably is inevitable, because they force viewers to make an effort—often a strenuous effort—to construct new kinds of visual images. The early reactions to the paintings of Cézanne and van Gogh are typical.

There is, however, one branch of art that can cause the construction of new and original visual images without making people uneasy. Cartoon characters, for instance.

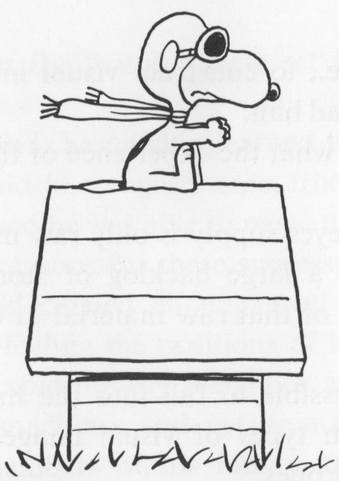


Figure 21. Snoopy, by Charles Schulz.
© 1966 United Feature Syndicate, Inc.

Before Charles Schulz imagined Snoopy, no one ever constructed such a visual image. Now our encounters with small dogs, not to mention doghouses, are livelier. Schulz's images of Snoopy have become part of our store of information from which we can draw to combine with raw material provided by our eyes in order to construct new visual images of our own.

To be sure, one reason why cartoons are accepted so easily is that they are extremely simple. Snoopy, it must be said at the risk of hurting his much damaged feelings, adds only a very little to anyone's collection of materials for better seeing. That little certainly is original and sparkling, but it is only

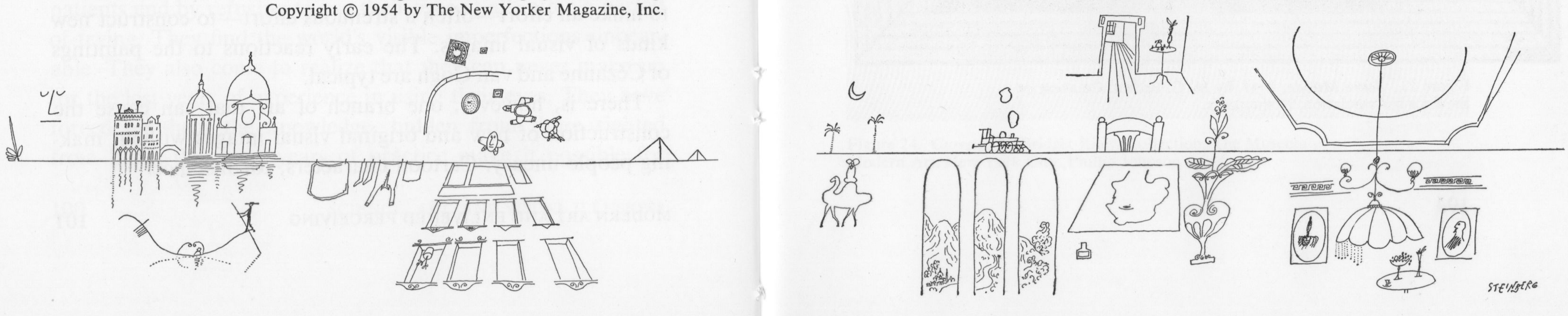


Figure 22. Drawing by Saul Steinberg.
Copyright © 1954 by The New Yorker Magazine, Inc.

a hint at what some of the great modern works of art can do in the way of expanding the capacity for perceiving.

Some of the drawings of Saul Steinberg provide stronger hints. The one below accomplishes the remarkable feat of adding to everyone's ways of reacting to a mere straight line on paper (Figure 22).

Steinberg makes us see this line, reading from right to left, first as the meeting of a sitting-room wall and ceiling, then as a tabletop, then as a railroad track across a viaduct, then as the horizon line of a desert, then as the edge of a sidewalk, then as a clothesline, then as a water line, and finally as a line in the process of being drawn across the page. At first we keep trying to see each segment separately. We can't do it. The line's transformations snatch at our attention and force us to construct visual images that constitute perceptions of what we never have perceived before. Our habits of perceiving are shaken up in a very healthy, helpful way.

Some of the woodcuts by M. C. Escher of Holland shake our perceiving habits even more vigorously. Close acquaintance with them might be especially useful to astronauts. See for instance Figure 23 on page 104.

Which way is up? Ordinarily the answer is obvious. It is not obvious in this drawing, nor is it obvious to anyone traveling weightless in space. No space traveler is going to behold a

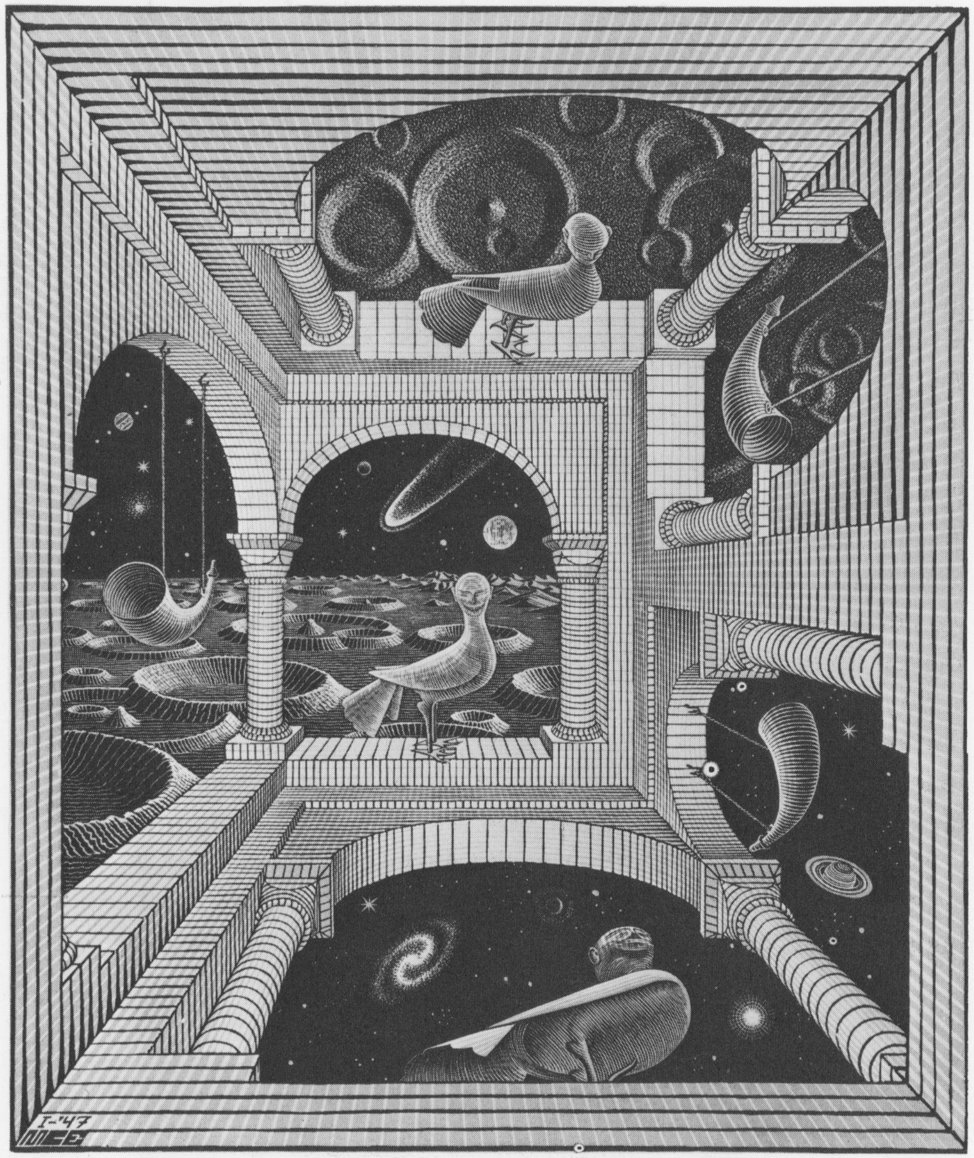


Figure 23. *Autre Monde*, 1947, by M. C. Escher. Courtesy of the Escher Association, Netherlands.

scene like this, but to get to know this drawing well is to experience vividly the possibility that the direction "up" can be uncertain. This prepares a person to deal a little more imaginatively with the confusing clues he encounters in space.

Many of the results of a fashion of painting called optical art also help viewers get used to confusing visual clues. The black-and-white painting by Bridget Riley shown in Figure 24 is an example.

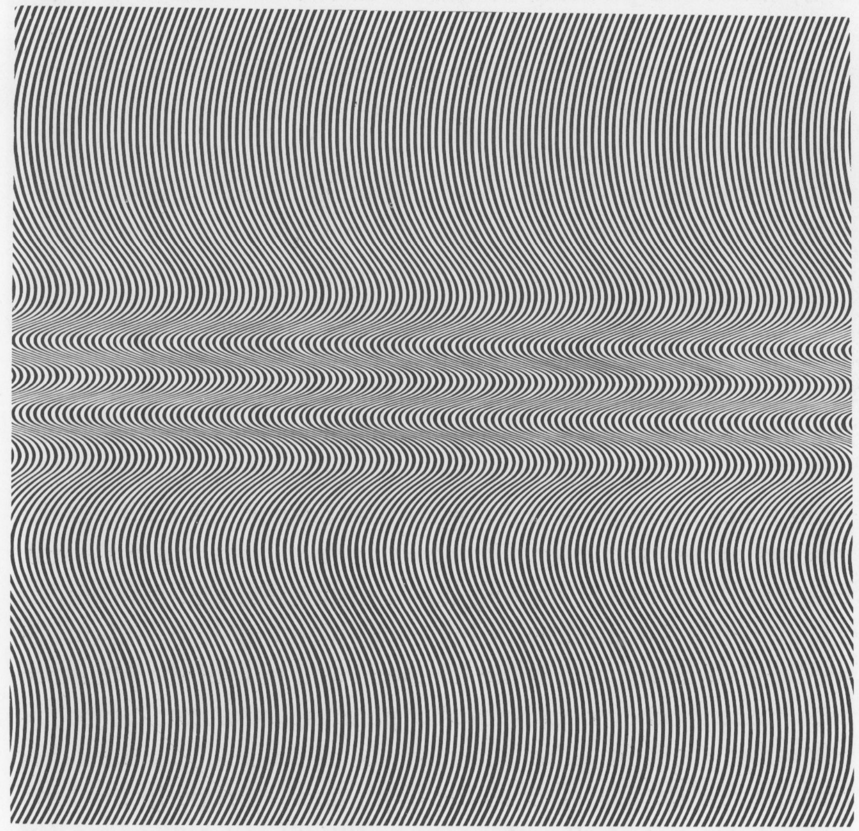


Figure 24. *Current*, by Bridget Riley. Collection, The Museum of Modern Art, New York City. Phillip Johnson Fund.

It is not yet fully understood why patterns of lines like this produce their odd effects. They can be disturbing to look at, and they even make some people experience something like seasickness. But try obscuring parts of the painting with your hands or with pieces of paper, so that you see only narrow vertical sections, then narrow horizontal sections. Also, try looking at such sections and at the whole painting with one eye closed. Experiments like this are, if nothing else, good exercise in constructing difficult visual images, and they gradually make the painting at least a little less disturbing.

Surrealist paintings also disturb some people. Surrealism rejects the everyday compulsion to try to be logical and concentrates on emotional associations of the kind usually encountered only in dreams. Of course, most surrealist painters put a great deal of highly logical thought and technically expert care into their work. But the best of them are free to create strikingly original visual images of commonplace objects. Witness the work by Salvador Dali in Figure 25.

This is an interesting painting at first sight, but if you put time and effort into looking at it, it becomes far more interesting than Snoopy, or Steinberg's straight line, or even Escher's weird world. Have you, for instance, noticed the dog yet? His head takes up most of the upper-right corner; his collar is the viaduct across the inlet. His head, in fact, also is a little hill. His muzzle is a river flowing down to the sea, and his rump is another hill. The middle of his back, blending into and out of the bowl of pears, also is the forehead and hair of the phantom face. Many other details in the painting stimulate us to incorporate them in quite different visual images. On the other hand, a few details, such as the cloth and the rope in the foreground, are not at all ambiguous.

Another interesting point about this painting is the way it

Figure 25. *Apparition of Face and Fruit Dish on a Beach*, by Salvador Dali. Courtesy of Wadsworth Atheneum, Hartford. Ella Gallup Sumner and Mary Catlin Sumner Collection.

plays with the illusion of depth. If you construct a visual image of the upper-right corner as a hill, a river, and a viaduct, you place it in the far distance. If you construct a visual image of the head of a dog, you bring that corner up close. And you can make the foreground either a beach or a table. These are only a few of the many ways in which Dali makes viewers work to enjoy the picture.

Such work and enjoyment can help viewers break bad habits of constructing only sure and final visual images. Pablo Picasso is another painter who provides help in getting away from such habits. He has worked in many styles. One was cubism, which grew out of some of Cézanne's experiments and with which Picasso and other tradition breakers outraged most

Figure 26. *Ambroise Vollard*, by Pablo Picasso. The Metropolitan Museum of Art, New York City. Elisha Whittelsey Collection, 1947.

of the art world in the first two decades of this century.

A good way to get a feeling for the mental images involved in cubism is by comparing one of Picasso's more conventional drawings with his cubist portrait of the same subject. Figure 26 shows the first, and Figure 27 is the cubist portrait.

Figure 27. *Ambroise Vollard*, by Pablo Picasso. Pushkin Museum, Moscow. Photograph courtesy of *Life* magazine.

Picasso divided the surface of this canvas into overlapping facets. Each facet presents what the eyes actually focus on at one spot before they leap to another spot. Ordinarily, a person blends the raw material gleaned in these takes and constructs a smooth continuous visual image like the one presented in the pencil portrait. In the cubist portrait Picasso deliberately prevents the viewer from doing such blending; the painting forces the viewer to see each take separately. The result is not only a striking portrait but also a fascinating pattern that weaves up and down and back and forth across the canvas, carrying the viewer's gaze with it.

Although this certainly is not painted "in perspective," it does create some illusion of depth because some of the facets tilt toward and some away from the viewer. In many of his other paintings Picasso deliberately restricted himself to two dimensions. Figure 28 is one of his most famous.

On the left is the painter at his canvas, his body indicated by a few straight lines and his head by the gray oval and quadrangle with three eyes. (Or are they two eyes and a mouth? This is one of many decisions Picasso leaves to the viewer because they are beside the point of the painting.) On the right are a table, a bowl containing a single round piece of fruit, and a plaster bust with eyes and/or mouth arranged like those of the painter. On the wall are what might be framed pictures, mirrors, windows, or whatever. Although the painter's head, the bowl, and the bust obscure what lies behind them, they are made to seem painted on, rather than to stand forward from, the background. The table and the tablecloth do not even obscure everything that lies behind them in quite the usual way.

Why all this vagueness? What *is* the point of the painting? The point is to make viewers see something usually ignored:

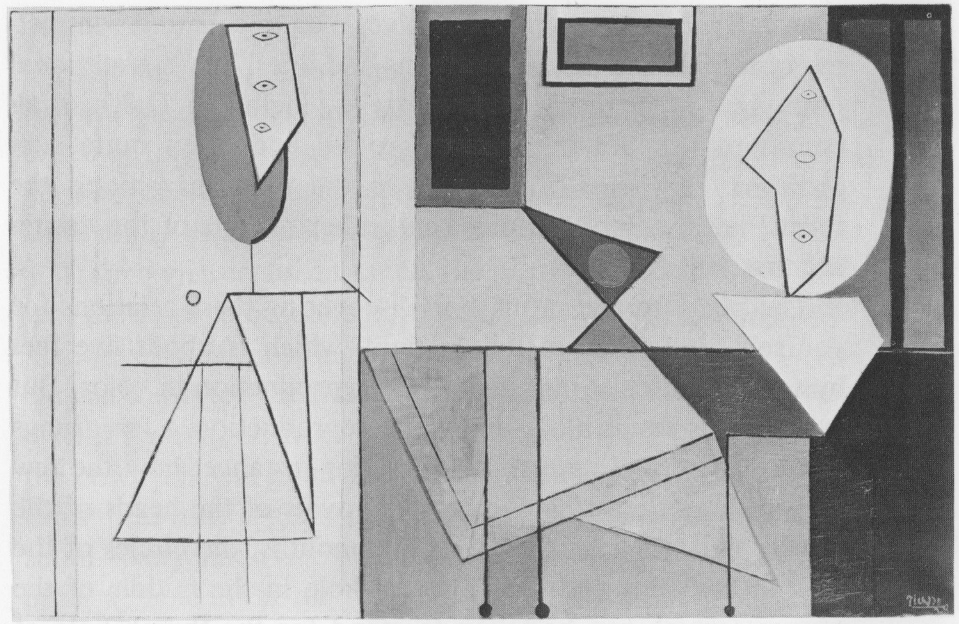


Figure 28. *The Studio*, by Pablo Picasso. Collection, The Museum of Modern Art, New York City. Gift of Walter P. Chrysler, Jr.

two-dimensional outlines of forms, and relationships among those outlines. All three-dimensional forms have two-dimensional outlines, but in constructing our ordinary mental images we ignore the outlines and concentrate on the details with which we fill them. Picasso here shows us how to do the reverse and is deliberately ambiguous about most of the few details shown inside the outlines.

It is a vivid demonstration, but not one that can be taken in at a glance or even in a few long stares. Although it seems much simpler than, for instance, Dali's *Apparition of a Face and a Fruit Dish on a Beach,* the enjoyment of it takes more effort, chiefly because it is still further outside ordinary experience. Every good painting involves a balancing and contrasting of similar and dissimilar forms and lines, but in traditional painting and in many modern styles, including Dali's, such considerations are in the background and often quite subordinate. In Picasso's *The Studio* the relations among the forms, lines, colors, textures, and other aspects of the design are first and foremost.

The pleasure and profit is in discovering these relations for yourself, preferably in the original, which is about five feet by seven feet, or at least in a large reproduction in color. But even in this small black-and-white reproduction a few things can be noted and enjoyed. Notice, for instance, how the few curved shapes echo each other: the ovals of the heads of the painter and the bust; their eyes and mouths; the circles of the fruit in the bowl and the apparent hole in the middle of the canvas (which can be taken to stand for the thumb hole of the painter's palette); the feet of the table legs. Quadrangles come in two kinds: boldly stated like that of the canvas, and understated like some of those formed by the table legs. Triangles are present in many varieties, including the truncated. Some lines unexpectedly parallel each other, and others, if you extend them in your imagination, intersect unexpectedly.

Why go through all this? In the first place, just for the pleasure of doing it. Anyone who makes no attempt to enjoy it is depriving himself unnecessarily. In the second place, because it adds greatly to your stock of materials for constructing visual images. You too can learn to perceive at least some aspects of the world around you in terms of simple geometric shapes and the relations among them.

But what does the picture mean? It means whatever you want it to mean. The notion that there is something wrong with reading meanings into a painting is absurd. No two persons perceive even a simple scene, let alone a complex painting like this one, in the same way or with the same feelings. Anyone who devotes himself to this one for a while is likely to see or feel in it something even Picasso has not seen or felt. And anyone who keeps returning to it is likely to change his mind many times about some of the meanings.

To one viewer, for instance, the plaster bust seems to represent the essence of inane pomposity. There is a pleasant little joke involved in making the round spot in the middle of the canvas stand for the thumb hole of the palette and matching it with the very abstract representation of the piece of fruit in the bowl. They are matched by their shapes and by their locations near the centers of their respective sections, and the small—very small—joke is that one is an actual hole and the other a "hole in the air" in the sense of occupying space. Also a little funny are the rectangles which seem to march with a sort of absurd stateliness around the picture, stepping up over the table, down from it, and under it. But there is no reason for anyone else to feel a need to share these reactions.

Hundreds of paintings in many of the styles that have developed since Cézanne and van Gogh began to question the old tradition are worth as much effort as *The Studio*. Some of these styles reject the idea of trying to represent anything that already exists in favor of creating designs that never existed before. One of the most determined painters in such a style was Holland's Piet Mondrian. Figure 29 shows one of his most stark compositions.

Encountering this for the first time, anyone unused to trying to take in new forms of art is likely to want to dismiss it as a joke or an attempt to put something over on the gullible. "There's nothing to it" is a standard complaint. But look for a while. Notice that the black lines divide the space unevenly,

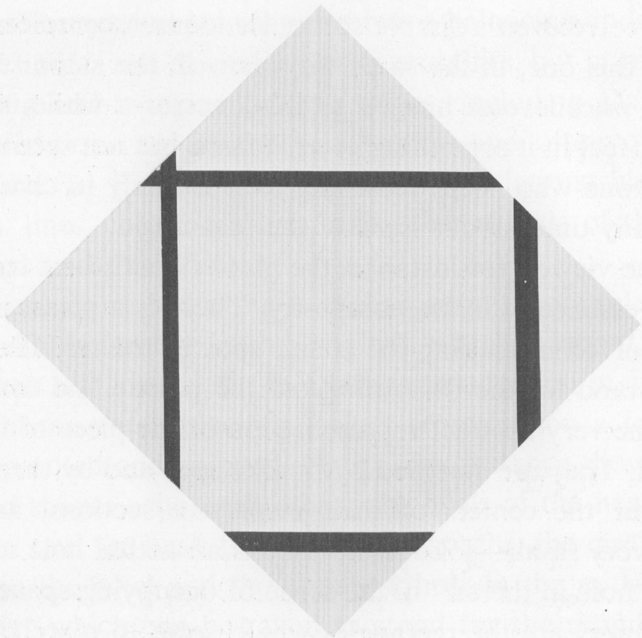


Figure 29. *Painting, I,* by Piet Mondrian.
Collection, The Museum of Modern Art, New York City.
Katherine S. Dreier Bequest.

yet the picture balances. Why does this balance occur?

Another complaint is that the picture seems cold and mechanical. That, said Mondrian, is exactly what he intended it to seem. He sought to create an image of the essence of the cold and mechanical.

Utterly different on the surface, except that it also usually is dismissed as a joke by people without experience in getting used to new ways of looking at things, is the work of Robert Rauschenberg. He incorporates sticks, stuffed birds, pieces of tin, old pillows, and other items of junk. Figure 30 shows

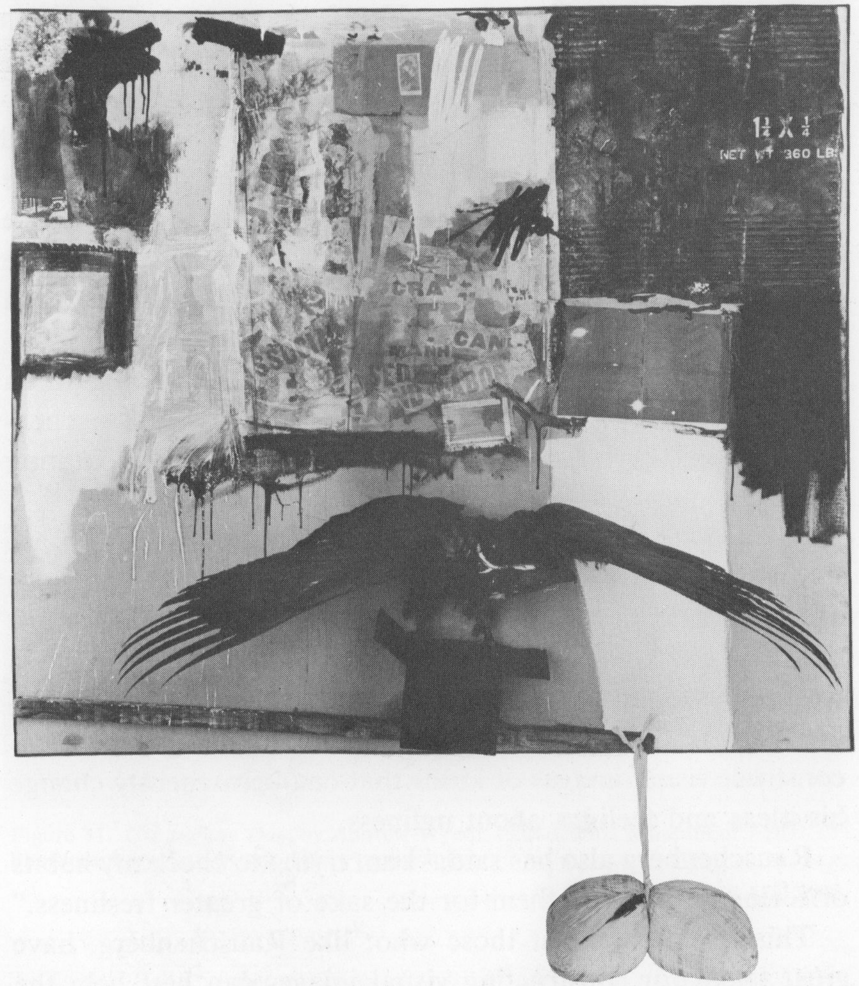


Figure 30. *Canyon,* by Robert Rauschenberg.
Collection, Illeana Sonnabend.
Photograph courtesy of Leo Castelli.

a mess, a spectacular mess. Yet it hangs together, even though parts of it hang or project all the way out of the canvas. Notice the more or less regular shapes, most of them approximately rectangles, and the highly irregular splotches and dribbles. These do not balance and echo each other in the cold, clear-cut way that Mondrian's black lines and white spaces balance out. Yet Rauschenberg has put together the messy elements of his picture so that they do balance each other in a messy kind of way.

"If you do not change your mind about something when you confront a picture you have not seen before," Rauschenberg has said, "you are either a stubborn fool or the painting is not very good."

The way in which you can change your mind while you are looking at a picture is by constructing visual images of kinds that you have never tried before or, perhaps, that you have tried but quickly rejected as too painful, too ugly. These two works by Mondrian and Rauschenberg are great mind changers. They lead anyone who puts effort into looking at them to construct visual images of kinds that can permanently change his ideas and feelings about ugliness.

Rauschenberg also has said, "I am trying to check my habits of seeing, to counter them for the sake of greater freshness."

This is exactly what those who, like Rauschenberg, have great talent for constructing visual images can best help the rest of us do. But this does not mean that the way in which a Rauschenberg goes about it—or the way of a Mondrian or a Dali or a Picasso—is the only or even the best way. New approaches to seeing and to painting can harden into habits as rigid as the habits they replace. As an antidote for such a tendency, consider the painting by Andrew Wyeth shown in Figure 31.

Figure 31. *Groundhog Day*, by Andrew Wyeth. Philadelphia Museum of Art. Photograph by A. J. Wyatt, Staff Photographer.

Many people who like to think of themselves as members of the avant-garde would give this little more than a glance. Many others who "don't know anything about art but know what they like" probably would like this and find it so familiar and comfortable that they too would not devote to it much more than a glance. Yet it can shake us loose from our ordinary habits of seeing much more effectively than can many pretentiously avant-garde paintings.

A viewer who puts effort into looking at *Groundhog Day* soon finds that it offers more than merely a recognizable representation of the corner of a quiet room and a bit of outdoors visible through a window. The fact is that, just as was the case in Picasso's *The Studio,* geometrical shapes are among the chief subjects of this picture.

Even at a glance, for instance, it is difficult not to notice that there is a great difference between the part of Wyeth's painting representing the indoors and that representing the outdoors, but it takes more than a glance to account for the difference. One of the important ingredients of the difference is in the nature of the geometrical forms indoors and out. Indoors the shapes and lines are either neat, clean straight edges —such as the various parts of the window, the wall molding under it, and the tabletop—or neat, clean curves, such as the plate, the cup, the cup handle, and the saucer. Outdoors many of the shapes and lines are ragged and jagged, especially the eye-catching shapes of the logs.

But Wyeth did not make this difference absolute, because that would have disconnected the two parts of the painting. He made several of the outdoor shapes and lines fairly regular: note the post and the top strand of barbed wire. He also made a few inside shapes and lines a little irregular; note the indistinct pattern of the wallpaper and, especially, the loose spot in the paper near the lower-left corner. Put your thumb over this spot and see how much colder and more rigid the indoor scene becomes and how much the integration of indoors and outdoors is weakened.

This painting of Wyeth's and those by Dali, Picasso, Mondrian and Rauschenberg discussed earlier make up, of course, only a tiny sample of what modern art has to offer; but they

demonstrate some of the most important ways in which art can help us break bad habits of seeing and learn to construct new kinds of visual images. Also, learning to respond to the challenges of modern art makes it possible to approach traditional Western art and the art of other cultures with new understanding. And that in turn opens endless possibilities for improving the use of the visual system.

The great achievement of modern scientific study of visual illusions in particular, and visual perception in general, is the new understanding that there is no end to learning to see.

The great achievement of original artists of all times and cultures is that they find new ways of seeing and help others to learn and enjoy them.

Bibliography

VISUAL ILLUSIONS

Gregory, Richard L. "Visual Illusions." *Scientific American*, November 1968. Here is a good summary of some of the recent studies of these phenomena.

Luckiesh, M. *Visual Illusions*. New York: Dover Publications, Inc., 1965. This paperback reissue of a book for general readers first published in 1922 summarizes much of the data preceding the development of modern theories about visual illusions.

Segall, M. H., Campbell, D. T., and Herskovits, M. J. *The Influence of Culture on Individual Perception*. Indianapolis: The Bobbs-Merrill Company, 1966.

———. "Cultural Differences in the Perception of Geometric Illusions." *Science*, 139:769–71 (February 22, 1963). The *Science* article summarizes and the book details the studies of how African and Filipino tribespeople differ from South African whites and Americans in their reactions to the Müller-Lyer and other illusions. The book also provides background material about other studies of cultural effects on perception.

SCIENTIFIC STUDY OF VISUAL PERCEPTION IN GENERAL

Ittelson, W. H., and Kilpatrick, F. P. "Experiments in Perception." *Scientific American*, August 1951. This highly readable article, together with the article by Ulric Neisser (below), provides an excellent summary of the scientific research and thinking about visual perception which have occurred in the last three decades.

Kohler, Ivo. "Experiments with Goggles." *Scientific American*, May 1962. Studies of the visual system's ability to adapt to visual distortions produced by goggles worn for several days or weeks are described.

Neisser, Ulric. "The Processes of Vision." *Scientific American*, September 1968.

Rock, Irvin, and Harris, Charles S. "Vision and Touch." *Scientific American*, May 1967. Experiments that seem to demonstrate the visual system's complete dominance over the touch senses are discussed.

Wittreich, Warren J. "Visual Perception and Personality." *Scientific American*, April 1959. This article presents studies of how emotional relationships affect a subject's perceptions of laboratory-produced distortions.

SCIENTIFIC STUDY OF SPECIAL ASPECTS OF VISUAL PERCEPTION

Bower, T. G. R. "The Visual World of Infants." *Scientific American*, December 1966. The studies discussed here indicate that infants can register a great deal of visual information, though they seem able to utilize very little of it.

Kaufman, Lloyd, and Rock, Irvin. "The Moon Illusion." *Scientific American*, July 1962. This article gives further information about the study of this illusion which was mentioned in the text.
Kolers, Paul A. "The Illusion of Movement." *Scientific American*, October 1964. Along with a report on recent studies of this particular illusion, the article includes good background information on the study of visual illusions in general.
Neisser, Ulric. "Visual Search." *Scientific American*, June 1964. Some preliminary studies of the visual system's as yet little understood ability to scan large collections of information and pick out certain items are described.
Oster, Gerald, and Nishijima, Yasunori. "Moiré Patterns." *Scientific American*, May 1963. These patterns, first used for decorative purposes and now favored by makers of so-called "optical art" objects, may also prove useful in making measuring instruments.
Thomas, E. Llewellyn. "Movements of the Eye." *Scientific American*, August 1968. This article contains good background material, as well as reports of some recent studies, about the activity of the eye as it searches for information.

THE INTERRELATIONSHIP OF SCIENCE AND ART IN THE STUDY AND IMPROVEMENT OF VISUAL PERCEPTION

Gibson, J. J. "*Pictures, Perspective, and Perception*." *Daedalus*, 89:216–27 (spring 1960).
———. *The Senses Considered as Perceptual Systems*. Boston: Houghton Mifflin Company, 1966.
Gibson, a Cornell University psychologist, has been studying visual perception for more than thirty years; he is one of the most original thinkers on and investigators of that subject. The *Daedalus* article brilliantly and readably summarizes many of his more interesting ideas and is especially good on the subject of how original artists can educate our attention. The book is difficult reading in spots but very much worth the attention of anyone who wants to pursue the subject of perception to the frontiers of research.
Gombrich, E. H. *Art and Illusion: A Study in the Psychology of Pictorial Representation*, 2nd edition. Princeton, New Jersey: Bollingen Series, Princeton University Press, 1961. Gombrich is an art historian and critic who is informed about modern psychological research on visual perception. This book shows how some of the central ideas developed in that research relate to various styles of art. The book is not easy to read, but profuse and intelligent illustrations help to clarify the difficult text.
Gregory, Richard L. *Eye and Brain*. New York: McGraw-Hill Book Company, 1966. This book for the general reader is written by the British psychologist whose work was mentioned in the text. It explains some fundamentals of current research on perception and some of the basic discoveries about visual illusions. It also briefly discusses a few different traditions of art.

May, Kenneth O. "Mathematics and Art." *The Mathematics Teacher*, October 1967. A pleasantly readable brief article about the relationship which has existed between these disciplines over the centuries. A good list of references for further reading is included.

ART IN GENERAL

Canaday, John. *Metropolitan Seminars in Art*, 12 volumes. New York: The Metropolitan Museum of Art, 1958. These twelve short books, each with twelve large color prints, give a survey of painting styles from cave art to modern art. They offer excellent suggestions about how to enjoy painting in general and these paintings in particular.
Gombrich, E. H. *The Story of Art*, 11th edition. London: Phaidon, 1966. This wonderfully readable short history makes an ideal companion piece to the Canaday series.

MODERN ART

Barr, Alfred H., Jr., editor. *Masters of Modern Art*. New York: The Museum of Modern Art, 1954. Well illustrated with color prints, this commentary on a selection of art from the museum's collection is a good brief summary of modern art.
Escher, Maurits Cornelis. *The Graphic Work of M. C. Escher*. London: Oldbourne Book Company, 1961. This volume offers a selection of weird and wonderful woodcuts.
Kepes, Gyorgy. *Language of Vision*. Chicago: Paul Theobold, 1944. Although disjointed and occasionally garbled or overwrought, this is a fascinating discussion of design in painting and commercial art. Some 300 illustrations demonstrate the ways in which modern painting, photography, advertising designs, and other graphic arts have influenced each other.
Meryman, Richard. *The Work of Andrew Wyeth*. Boston: Houghton Mifflin Company, 1968. The text is mostly chitchat, but the 121 full-page color prints of Wyeth's drawings and paintings are magnificent.
"Picasso." *Life* magazine, December 27, 1968. Although this issue of *Life* devoted entirely to Picasso inevitably contains a lot of chitchat, it also includes a sizable selection of his works and offers a good starting point for learning to enjoy them.
Seitz, William C. *The Art of Assemblage*. New York: The Museum of Modern Art, 1961. This catalog from an exhibition of works that combine painting with objects is a good introduction to the subject.

UNIQUE

Parmenter, Ross. *The Awakened Eye*. Middletown, Connecticut: Wesleyan University Press, 1968. This book, by a former music critic of *The New York Times*, is like no other. Parmenter tells how he learned to make better—magnificently better—use of his visual system, and suggests ways that other people can expand their visual awareness. His advice is exciting to follow.

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Science, Art, and Visual Illusions
by Robert Froman
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Visual illusions have intrigued artists and scientists for a long time. Painters learned to create the illusion of depth several centuries ago. The examples in this book show how ingenious and delightful many of their approaches were. Modern artists have tried to unsettle fixed habits of seeing by introducing alternatives to realistic painting. Examples of the work of Picasso, Dali, Rauschenberg and others show how other kinds of visual illusions have contributed to this dramatic upheaval.

Scientists have made many fascinating observations about perception by studying visual illusions. One of the most startling observations has been the discovery that people who are used to seeing depth illusion in paintings and photographs are more susceptible to certain visual illusions than people who have never had this experience.

Using paintings and drawings to demonstrate when and how visual illusions occur, Robert Froman introduces young reader-viewers to a stimulating, thoroughly enjoyable subject.

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About the Author

Robert Froman was born in Big Timber, Montana. He lived in Caldwell, Idaho, for a number of years and then attended Reed College before moving to the East Coast. His books for teen-age readers cover such topics as spiders and snakes, the physics of baseball, salt, how living beings communicate, and the human senses. His interests include poetry, mathematics, art, and most branches of science. Mr. Froman now lives in Tompkins Cove, New York, with his wife Elizabeth.

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