The Psychology of Perspective and Renaissance Art

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Brunelleschi’s friends were amazed at the compelling impression of depth they experienced when they looked at his panel through the peephole in its back. How compelling could it have been? In this chapter, we will see that Brunelleschi had discovered an almost optimal technique to wrest an illusion of depth from a picture painted on a flat surface.

If one wishes to gauge the intensity of an experience of depth induced by a picture, it is best to compare it to the most effective technique available: the stereoscope. Figure 4.1 shows a stereoscopic pair of drawings prepared by Sir Charles Wheatstone in 1831 to demonstrate his discovery of the basis of stereoscopic vision to the Royal Society (Wheatstone, 1838). If you look at them as instructed in the caption, only one picture will be seen by each eye, and you will experience the full strength of the effect. To understand the effect, hold an object in your hand and look at it first with one eye and then with the other. Because each eye sees the object from a slightly different vantage point, the object casts a somewhat different image on the retina of each eye. Nevertheless, when both eyes are open we see only one object; we do not see double as we might naively expect. Of course, the visual system cannot fuse two images that are very different. To see how limited is our ability to fuse disparate images, hold up your two hands, side by side, a few inches apart, their backs facing your eyes, index fingers pointing up, about half a foot before your nose, and focus on one of your fingers. Make sure that you can see both fingers clearly. If you can’t, move them closer to each other. Now slowly move the hand at which you were looking closer or further away. Over a short distance, both fingers will remain in focus, but after your hand has moved about an inch you will notice that the finger at rest looks double. This is because the visual system can only fuse the two disparate images that a single object casts on the two retinas if the so-called retinal disparity between these two images is not too large. The retinal disparity of the finger you were looking at remained zero while the retinal disparity of the other finger grew as you moved it away. Wheatstone demonstrated that if retinal disparity is small the two images not only fuse but also give rise to a most compelling experience of depth, called stereopsis.

What is the function of stereoscopic vision? It gives us the ability to accurately gauge and compare distances in our immediate environment, approximately within range of a long jump, that is, a range of a few yards. For instance, you will find it extremely difficult — indeed almost impossible — to perform a task requiring fine perceptual motor coordination at close range (such as threading a needle) with one eye closed.

There was a time when psychologists, impressed with the critical role played by stereoscopic vision in the performance of such perceptual-motor skills,
thought that the world appeared flat when seen through one eye. The truth is that one-eyed people are not really handicapped at all when it comes to visual tasks that require them to aim action toward long-range targets, such as throwing a ball or landing an airplane. From this observation concerning our ability to effectively gauge depth with one eye, we might predict that a monocularly viewed picture that projects onto the retina the same image as might be projected by a three-dimensional scene would be seen in depth, because the picture would then be a projective surrogate for the scene. A projective surrogate was considered by Gibson (1954) to be a special case of the more general class of surrogates:

A surrogate will be defined as a stimulus produced by another individual which is relatively specific to some or event not at present affecting the sense organs of the perceiving individual. (pp. 5–6)

Surrogates fall into two classes: conventional and nonconventional. The nonconventional surrogates can also be subdivided:

Non-conventional, projective or replicative surrogates (are) characterized by . . . the theoretical possibility of the surrogate becoming more and more like the original until it is undistinguishable from it. (p. II)

It is easy to create a projective surrogate: One draws a picture in rigorous perspective and places the observer’s eye at the picture’s center of projection. Unfortunately, the expectation that an exact projective surrogate would be seen in depth is not confirmed. Although we usually interpret such a picture as the representation of a three-dimensional scene when we view it from the appropriate vantage point, the impression is no more compellingly three-dimensional than if we viewed the picture from a different vantage point. The vividness of stereopsis is absent from this experience. Thus to view a rigorous perspective picture from its center of projection is not enough to transform our impression of a picture that represents depth into an experience almost indistinguishable from the perception of objects deployed in depth. At this point, we might conclude that only disparate images seen by the two eyes can produce the sort of vivid experience of depth we are discussing. Such a conclusion would be premature, as we shall presently see. Indeed, one might say that the reason we do not see vivid depth in pictures (whether viewed with one eye or two) is not because they fail to fulfill the necessary conditions for such perception, but rather because pictures bear two kinds of incompatible information, namely, information about the three-dimensional scene they represent, as well as information about their own two dimensionality. It follows that if we could rid ourselves of the latter, the former information should produce a vivid and compelling experience of depth, as striking as stereopsis.

One way to reduce the noticeability of the surface of a picture is to have the spectator view the picture from a long distance away. If the picture is so large as to enable the spectator to view the picture from afar, stereoscopic vision, which can under some conditions diminish the experience of depth by supplying us with information regarding the flatness of the picture plane, is ineffectual because of the distance. Indeed, it is unlikely that stereoscopic cues can tell us much about the flatness or the orientation of a picture that is more than 200 cm. (about 2 yd.) away from us (Ono and Comerford, 1977). So if the
Figure 4.2: Fra Andrea Pozzo, *Saint Ignatius Being Received into Heaven* 1691–4. Fresco. Ceiling of the Church of Sant’Ignazio, Rome.
The spectator’s eyes are approximately at the center of projection of the picture and the picture plane is distant, we should perceive the picture in vivid depth. The typical work of art based on this principle is a wall or ceiling painting. It represents a scene in an architectural setting that, even though imaginary, is a continuation of the real architecture of the hall. The best example is Pozzo’s ceiling fresco in the Church of Sant’Ignazio in Rome (Figure 4.2). The painting is a very precise central projection of an imaginary architecture onto the hemicylindrical ceiling of the church, which uses a center of projection at the eye level of a person standing on a yellow marble disk in the middle of the nave. Maurice Henri Pirenne in his important book *Optics, Painting, and Photography* (1970) writes about Pozzo’s ceiling:

The photograph, taken from the relevant yellow marble disk, shows the painting as it is meant to be seen. It shows little of the real architecture of the church, except the windows. To the spectator standing on the marble disk, the painted architecture appears in three dimensions as an extension of the real architecture. This photograph fails to give the overwhelming impression thus produced in the spectator by this vast painting . . .

The result of all this work is striking . . . from the floor, the spectator is unable to see the painted surface, qua surface. It is impossible to determine where the ceiling actually is. From the position marked by the yellow marble disk, the arches supported by columns at both ends of the ceiling are seen to stand upright into space. They are seen in three dimensions, with a strength of illusion similar to that given by the stereoscope . . . (Caption of Figure 7.5, p. 81; p. 84)

The Pozzo ceiling is the culmination of a tradition of illusionistic painted architectures begun by Mantegna. In the Ducal Palace in Mantua (Figure 4.3), he had painted an illusionistic parapet that appears to break through the ceiling. Around it, in extreme foreshortening, we see several putti precariously perched on a narrow ledge and other figures peering down over the parapet. Almost half a century later, Peruzzi undertook a far more ambitious exercise in illusionistic imaginary architecture. On the walls of a room on the second floor of the Roman villa he designed for Agostino Chigi, the Pope’s banker, he painted frescoes that represent balconies from which one can see beautiful views of Rome (Figure 4.4).

Box 4.1: Photographing illusionistic walls

Most of the published photographs of this wall fresco do not do justice to the power of the illusion it imparts, because they are not taken from the center of projection, which is not in the middle of the room, but in the doorway across the room from the right-hand door seen in Figure 4.4. For this reason, the imaginary architecture looks in these photographs as if it were askew with respect to the rest of the room. An exception is shown in Figure 4.5. See also Footnote 3, Chapter 5.

Neither of these works is extensive enough to provide an illusion as powerful as Pozzo’s, nor did either artist prescribe an ideal vantage point from which the painting ought to be seen.

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2 It is rather easy to dismiss this ceiling as kitsch, an example of the “enticing and popular iconography of sentimental baroque” that, according to Wylie Sypher (1978, p. 246) “accompanied a decay in rational theology and the rise of mere dogma in its place. The sensorium in its most literal activity became the instrument of faith. As the baroque imagination materialized itself at the familiar level, illusion became mere deception whenever the artist gave up the double world courageously erected by high-baroque art, and tried to obliterate entirely the distinction between the heavenly realm and the world of the worshipper... Heaven is entirely accessible in Fra Andrea Pozzo’s ceiling (1685 ff.) in Sant’ Ignazio, where the majestic soaring architecture, itself painted, is almost obliterated by the swarming angelic hosts flying about the very windows of the clerestory and obscuring the values of both illusion and reality by their facile descent. This art makes transubstantiation ‘easy’ and credible.”

3 A survey of perspective paintings on non-vertical surfaces, which includes many of the works in this tradition, is Santapá (1968).

4 Plural of putto, which is the Italian term for “cherub.”
A second way to diminish the impact of cues for flatness was discovered about the middle of the seventeenth century when there flourished in the Netherlands a popular art — the “perspectyfkas,” the perspective cabinet. Some of its practitioners were major artists of the Delft School, such as Pieter de Hooch and Jan Vermeer. Pirenne describes one of them:

There is in the National Gallery in London a cabinet containing two peep-shows painted by S. van Hoogstraten (1627–78). One of these peep-shows [reproduced in Mastai, 1975, plate 1971] represents a seventeenth century Dutch interior consisting of a hall with a black and white tiled pavement, opening on two furnished rooms with a view of a street and a canal. All this appears in three dimensions when viewed through the peep-hole. This peep-show looks very much like a real interior, extending far beyond the dimensions of the cabinet. The scene is painted in perspective on the inside surface of the box, from one single centre of projection, the centre of the peep-hole. The painting is carried over in a continuous fashion from one wall of the box to another. In the hall the tiles, two chairs and a dog are painted partly on the wall, and partly on the floor of the box. It is hardly possible to tell on which surface of the cabinet the various parts are painted. When something of the actual wall of the cabinet can be distinguished, the painted view is seen ‘through’ the wall. (1970, p. 85, footnote I; see also Wheelock, 1977)

Why is it “hardly possible to tell on which surface of the cabinet the various parts are painted”? Is it only due to the removal of stereoscopic cues to the disposition of the internal walls of the box? We should also consider the possibility that it is due to the peephole itself.

To understand peepholes, we must first deal with certain properties of lenses, which also apply to the lens of the eye. Consider a lens and a film (Figure 4.6). Consider also a field of object points (the gray region in panel A of Figure 4.6), the images of which...
are formed on the film by the lens. Even the best of lenses introduces some blur; in other words, the image of a point on an object is a circular region called the circle of confusion. The object points for which the circle of confusion is minimal are said to be in the focus plane. Object points that are less in focus than those in the focus plane, but are not objectionably blurred, are said to be in focus (panels B and C of Figure 4.6). The distance between the nearest object point that is in focus and the farthest object point that is in focus is called the depth of field of that lens.

Just as the distance of the focal plane of most camera lenses can be varied from infinity to a few feet, the visual system can change the shape of the eye’s lens (a process called accommodation and thereby vary the distance of the focal plane of the eye (over a greater range than most camera lenses). If an object is fairly close to the eye (say, less than 10 ft. away), the accommodation of the eye can be a source of information regarding the distance of the object; that is, the accommodation of the eye can serve as a range finder.

Cameras have diaphragms that make it possible to mask off part of the lens, to change the aperture size; similarly, the iris can change the size of the pupil. The smaller the aperture or pupil size, the less light hits the film or the retina. Changing the aperture size also affects depth of field. The smaller it is, the greater the depth of field (see Figure 4.6, panels D and E). Now if a peephole is so small that it effectively reduces the size of the pupil, it is called an artificial pupil. An artificial pupil can enhance pictorial depth by increasing depth of field and thus minimizing the value of information about distance derived from accommodation. For instance, when one looks into a relatively small perspective cabinet (as most are), the eye must focus on the painted surfaces inside the box; because the range is small, one might expect accommodation to disclose the distance of the painted surfaces and thereby diminish the illusion. This may be so, but if the peephole is very small, we should expect the viewer’s depth of field to be increased. In such a case, the painting would be nicely in focus even if the eye accommodated so that its focus plane would be at the distance one might expect the walls of a real room to be.

In addition to affecting the depth of field, a peephole can also reduce information about the flatness of a painting just by truncating the visual field — by removing from sight the immediate foreground, surrounding objects, the picture’s margin, and the unfocused (but possibly important) sight of one’s nose (see Schlosberg, 1941, and Hagen and Jones, 1978).

So Brunelleschi’s use of a peephole in his first demonstration was instrumental in producing a compelling experience of depth for two reasons: First, it increased the effectiveness of the illusion by forcing the viewer to place his or her eye at the center of projection of the perspective (thus making the picture a projective surrogate for the scene); second, it reduced the viewer’s information regarding the flatness of the picture plane.

There is another aspect of Brunelleschi’s technique that merits discussion. Although Brunelleschi’s peepshow was similar to seventeenth-century perspective cabinets, it appears to have anticipated certain techniques for the enhancement of depth in monocularly viewed pictures that were not discovered until the first two decades of this century. Here is Harold Schlosberg’s (1941) summary of these discoveries:

In the period around 1910, when interest in
Box 4.2: Viewing from the center of projection vs. the removal of flatness information

The relative importance of these two factors is not known. For instance, we do not know the extent to which the apparent three-dimensionality of a display is diminished by the presence of stereoscopic cues to flatness. This question could be resolved by comparing the apparent three-dimensionality of a perspective painting seen monocularly through one peephole at the center of projection to the apparent three-dimensionality of the same painting seen binocularly through two peepholes on either side of the center of projection. An experiment by Adams (1972) compares these two conditions and includes a third: viewing through an artificial pupil. Although his data show no effect of the three modes of viewing, I do not consider the experiment definitive on this issue because of the method Adams used in determining perceived depth: He presented a picture representing a floor consisting of rectangular tiles, and a wall parallel to the picture plane that is the far wall of the room into which the spectator is gazing. This wall was also divided into a row of tiles. The observers were asked to vary the height of the tiles on the far wall until they matched the depth of the floor tiles. Subjects systematically underestimated the depth of these foreshortened floor tiles by matching them to wall tiles that were always shorter in height than in breadth, whereas geometric considerations would predict the floor tiles to appear elongated in depth under certain conditions, square under other conditions, and elongated in width under a third set of conditions. This result could be accounted for by the subjects having performed a task that was a compromise between the task they were expected to perform, which required a judgment of depth (but may be difficult), and a comparison of the two-dimensional forms of the foreshortened tiles on the floor and the frontal tiles on the wall (which is likely to be easy). If the task that the subjects performed did not involve the judgment of depth to the extent anticipated, one cannot infer much about the different modes of viewing from the negative results reported.
stereoscopy was high, it was widely known that the “plastic” effect could be obtained almost as well by viewing a single picture through a lens as by the use of disparate pictures in the binocular stereoscope. The plastic depth that can be obtained monocularly is very striking, and must be seen to be appreciated. For optimal results the viewing lens should have the same focal length as the camera lens with which the picture was taken, but any ordinary reading glass works fairly well on pictures from 1–3 in. in size. In a typical snapshot of a person against a mixed background, the person stands out clearly, and plastic space can be seen between him and the background. In a good picture the person takes on solidity and roundness, with the slope of the lapel and the angle of the arms clearly in three dimensions. (p. 601)

For our purposes, it is most important to note that a similar effect can be achieved by “looking at a picture monocularly in a mirror. The mirror seems to break up the surface cues and may well have less obvious effects, such as destroying orientation” (Schlosberg, 1941, p. 603). This is exactly what Brunelleschi did.

In addition to all this non-experimental evidence regarding the impact of Brunelleschi’s peepshow, it has been shown in experiments that a proper central projection can be mistaken for a real scene if viewed monocularly from the center of projection. For instance, Smith and Smith (1961) asked subjects to throw a ball at a target in a room that they could view through a peephole (see Figure 4.7). Two groups of subjects threw the ball at a target in a real room. The subjects in one group were actually able to see the room through the peephole, whereas the subjects in the other group thought they were looking at the room but actually were looking at a photograph of the room. When subjects looked through the peephole at the real room, their throws were on the average quite accurate; when subjects looked through the peephole at a photograph of the room, the average throw was not systematically longer or shorter, but it was considerably more variable\textsuperscript{6} But what is more important than the similar accuracies of the throws was the absence of any awareness on the part of subjects that they had been seeing photographs in the viewing apparatus. In other words, neither in their performance of the ball-throwing task nor in their interpretation of the situation did the participants show any sign that the picture looked different from an actual room. And this implies that the Brunelleschi peephole can give rise to an illusion so strong that it could properly be called a delusion. We will return to this point in Chapter 6.

\textsuperscript{6}The authors speculate that direct view of the targets permitted some monocular parallax and thus reduced the variability of the throws.
Figure 4.7: Experimental apparatus for Smith and Smith's experiment.