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Indirect Perception.
Irvin Rock.
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Chapter 9

Orientation and Form

Irvin Rock

Many common experiences of everyday life that we take for granted present challenging scientific problems. In the field of visual perception one such problem is why things look different when they are upside down or tilted. Consider the inverted photograph [see fig. 9.1]. Although the face is familiar to most Americans, it is difficult to recognize when it is inverted. Even when one succeeds in identifying the face, it continues to look strange and the specific facial expression is hard to make out.

Consider also what happens when printed words and words written in longhand are turned upside down. With effort the printed words can be read, but it is all but impossible to read the longhand words [see fig. 9.2]. Try it with a sample of your own handwriting. One obvious explanation of why it is hard to read inverted words is that we have acquired the habit of moving our eyes from left to right, and that when we look at inverted words our eyes tend to move in the wrong direction. This may be one source of the difficulty, but it can hardly be the major one. It is just as hard to read even a single inverted word when we look at it without moving our eyes at all. It is probable that the same factor interfering with the recognition of disoriented faces and other figures is also interfering with word recognition.

The partial rotation of even a simple figure can also prevent its recognition, provided that the observer is unaware of the rotation. A familiar figure viewed in a novel orientation no longer appears to have the same shape [see figs. 9.3, 9.4]. As Ernst Mach pointed out late in the 19th century, the appearance of a square is quite different when it is rotated 45 degrees. In fact, we call it a diamond.

Some may protest that a familiar shape looks different in a novel orientation for the simple reason that we rarely see it that way. But even a figure we have not seen before will look different in different orientations [see fig. 9.5]. The fact is that orientation affects perceived shape, and that

Originally published in *Scientific American* 230, 1 (1974): 78–85, under the title “The Perception of Disoriented Figures.” Reprinted with permission.



Figure 9.1
Inverted photograph of a famous American demonstrates how difficult it is to recognize a familiar face when it is presented upside down. Even after one succeeds in identifying the inverted face as that of Franklin D. Roosevelt, it continues to look strange.

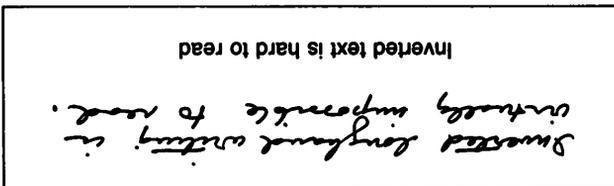


Figure 9.2
Inverted words are difficult to read when they are set in type, and words written in longhand are virtually impossible to decipher. The difficulty applies to one's own inverted handwriting in spite of a lifetime of experience reading it in the normal upright orientation.



Figure 9.3

Square and diamond are two familiar shapes. The two figures shown here are identical; their appearance is so different, however, that we call one a square and the other a diamond. With the diamond the angles do not spontaneously appear as right angles.

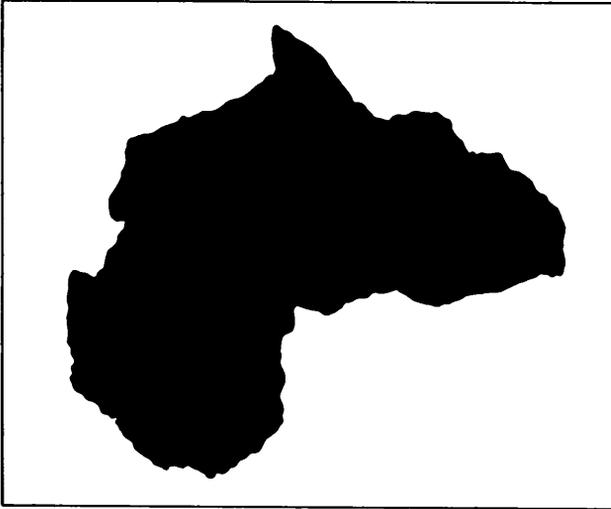


Figure 9.4

“Unfamiliar” shape shown here becomes a familiar shape when it is rotated clockwise 90 degrees. In a classroom experiment, when the rotated figure was drawn on the blackboard, it was not recognized as an outline of the continent of Africa until the teacher told the class at the end of the lecture that the figure was rotated out of its customary orientation.

the failure to recognize a familiar figure when it is in a novel orientation is based on the change in its perceived shape.

On the other hand, a figure can be changed in various ways without any effect on its perceived shape. For example, a triangle can be altered in size, color and various other ways without any change in its perceived shape [see fig. 9.6]. Psychologists, drawing an analogy with a similar phenomenon in music, call such changes transpositions. A melody can be transposed to a new key, and although all the notes then are different, there is no change in the melody. In fact, we generally remain unaware of

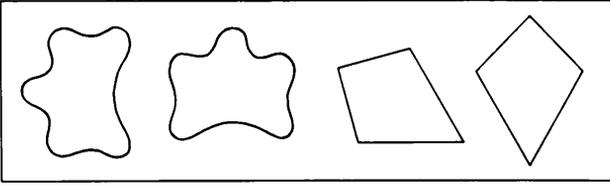


Figure 9.5

Novel or unfamiliar figures look different in different orientations, provided that we view them naïvely and do not mentally rotate them. The reason may be the way in which a figure is “described” by the perceptual system. The figure at the far left could be described as a closed shape resting on a horizontal base with a protrusion on its left side and an indentation on its right side. The figure adjacent to it, although identical, would be described as a symmetrical shape resting on a curved base with a protrusion at the top. The second figure from the right could be described as a quadrilateral resting on a side. The figure at the far right would be described as a diamondlike shape standing on end.

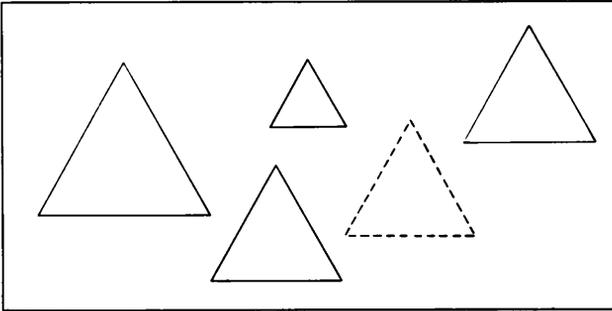


Figure 9.6

Alteration in size, color, or type of contour does not change the perceived shape of a triangle. Even varying the location of the triangle’s retinal image (by looking out of the corner of your eyes or fixating on different points) does not change perceived shape.

the transposition. Clearly the melody derives from the relation of the notes to one another, which is not altered when the melody is transposed. In much the same way a visual form is based primarily on how parts of a figure are related to one another geometrically. For example, one could describe a square as being a four-sided figure having parallel opposite sides, four right angles and four sides of equal length. These features remain unchanged when a square is transposed in size or position; that is why it continues to look like a square. We owe a debt to the Gestalt psychologists for emphasizing the importance in perception of relations rather than absolute features.

Since a transposition based on rotation also does not alter the internal geometric relations of a figure, then why does it look different in an

altered orientation? At this point we should consider the meaning of the term orientation. What changes are introduced by altering orientation? One obvious change is that rotating a figure would result in a change in the orientation of its image on the retina of the eye. Perhaps, therefore, we should ask why different retinal orientations of the same figure should give rise to different perceived shapes. That might lead us into speculations about how the brain processes information about form, and why differently oriented projections of a retinal image should lead to different percepts of form.

Before we go further in this direction we should consider another meaning of the term orientation. The inverted and rotated figures in the illustrations for this article are in different orientations with respect to the vertical and horizontal directions in their environment. That part of the figure which is normally pointed upward in relation to gravity, to the sky or to the ceiling is now pointed downward or sideways on the page. Perhaps it is this kind of orientation that is responsible for altered perception of shape when a figure is disoriented.

It is not difficult to separate the retinal and the environmental factors in an experiment. Cut out a paper square and tape it to the wall so that the bottom of the square is parallel to the floor. Compare the appearance of the square first with your head upright and then with your head tilted 45 degrees. You will see that the square continues to look like a square when your head is tilted. Yet when your head is tilted 45 degrees, the retinal image of the square is the same as the image of a diamond when the diamond is viewed with the head upright. Thus it is not the retinal image that is responsible for the altered appearance of a square when the square is rotated 45 degrees. The converse experiment points to the same conclusion. Rotate the square on the wall so that it becomes a diamond. The diamond viewed with your head tilted 45 degrees produces a retinal image of a square, but the diamond still looks like a diamond. Needless to say, in these simple demonstrations one continues to perceive correctly where the top, bottom and sides of the figures are even when one's posture changes. It is therefore the change of a figure's perceived orientation in the environment that affects its apparent shape and not the change of orientation of its retinal image.

These conclusions have been substantiated in experiments Walter I. Heimer and I and other colleagues have conducted with numerous subjects. In one series of experiments the subjects were shown unfamiliar figures. In the first part of the experiment a subject sat at a table and simply looked at several figures shown briefly in succession. Then some of the subjects were asked to tilt their head 90 degrees by turning it to the side and resting it on the table. In this position the subject viewed a series of

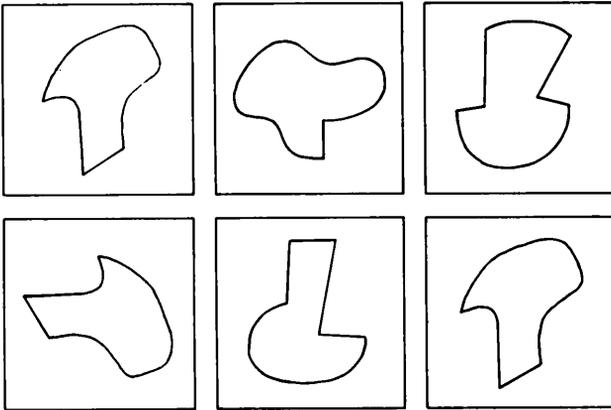


Figure 9.7

Rotation of retinal image by tilting the head 90 degrees does not appreciably affect recognition of a novel figure (*figure at top left*). Subjects first viewed several novel targets while sitting upright. Then they were shown a series of test figures (*all others*) and were asked to identify those they had seen before. Some subjects tilted their head 90 degrees; others viewed the test figures with their head upright. Tilted-head subjects failed to recognize figures that were retinally “upright” (for example figure at bottom left) about as much as upright viewers did (to whom such figures were not retinally upright). Tilted-head subjects recognized environmentally upright figures (*bottom right*) as often as upright viewers did.

figures [see fig. 9.7]. Most of the figures were new, but among them were some figures the subject had seen earlier. These figures were shown in either of two orientations: upright with respect to the room (as they had been in the first viewing) or rotated 90 degrees so that the “top” of the figure corresponded to the top of the subject’s tilted head. The subject was asked to say whether or not he had seen each figure in the first session. He did not know that the orientation of the figures seen previously might be different. Other subjects viewed the test figures while sitting upright.

When we compared the scores of subjects who tilted their head with subjects who sat upright for the test, the results were clear. Tilted-head subjects recognized the environmentally upright (but retinally tilted) figures about as well as the upright observers did. They also failed to recognize the environmentally tilted (but retinally upright) figures about as often as the upright subjects did. In other words, the experiments confirmed that it is rotation with respect to the up-down and left-right coordinates in the environment that produces the change in the perceived shape of the figure. It is not rotation of the retinal image that produces the change, since altering the image’s orientation does not adversely affect recognition and preserving it does not improve recognition.



Figure 9.8

Figures with intrinsic orientation appear to have a natural vertical axis regardless of their physical orientation. A region at one end of the axis is perceived as top.

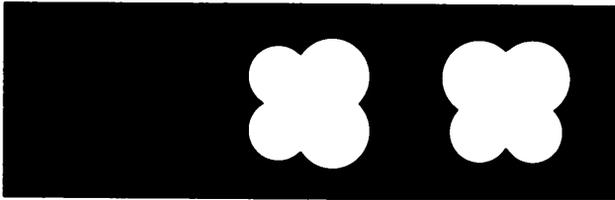


Figure 9.9

Impression of symmetry is spontaneous only when a figure is symmetrical around a vertical axis. Subjects were asked to indicate which of two figures (*middle and right*) was most like the target figure (*left*). The figure at right was selected most frequently, presumably because it is symmetrical around its vertical axis. If the page is tilted 90 degrees, the figure in the middle will now be selected as being more similar to the target figure. Now if the page is held vertically and the figures are viewed with the head tilted 90 degrees, the figure at right is likely to be seen as being the most similar. This suggests that it is not the symmetry around the ego-centric vertical axis on the retina but rather the symmetry around the environmental axis of the figure that determines perceived symmetry.

In another experiment subjects viewed an ambiguous or reversible figure that could be perceived in one of two ways depending on its orientation. For example, when one figure that looked like a map of the U.S. was rotated 90 degrees, it looked like the profile of a bearded man. Subjects were asked to rest their head on the table when viewing the ambiguous figures. The question we asked ourselves was: Which “upright” would dominate, the retinal upright or the environmental upright? The results were decisive. About 80 percent of the subjects reported seeing only the aspect of the ambiguous figure that was environmentally upright, even though the alternative was upright on their retina [see fig. 9.10].

Why does the orientation of a figure with respect to the directional coordinates of the environment have such a profound effect on the perceived

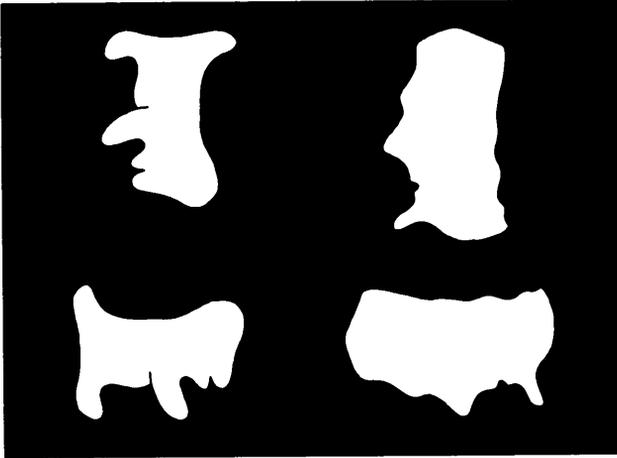


Figure 9.10

Ambiguous figures can be perceived in different ways depending on the orientation assigned to them. Figure at left can look like the profile of a man's head with a chef's hat (*top left*) or, when rotated 90 degrees, like a dog (*bottom left*). Figure at right can look like the profile of a bearded man's head (*top right*) or like a map of the U.S. (*bottom right*). When subjects with their head tilted 90 degrees to one side viewed these ambiguous figures (*direction of subject's head is shown by arrow*), they preferentially recognized the figure that was upright in the environment instead of the figure that was upright on the retina.

shape of the figure? The answer I propose is that perceived shape is based on a cognitive process in which the characteristics of the figure are implicitly described by the perceptual system. For example, the leftmost shape in fig. 9.5 could be described as a closed figure resting on a horizontal base with a protrusion on the figure's left side and an indentation on its right side. The colored figure to the right of it, although it is identical and only rotated 90 degrees, would be described quite differently, as being symmetrical with two bumps on the bottom and with left and right sides more or less straight and identical with each other. I am not suggesting that such a description is conscious or verbal; obviously we would be aware of the descriptive process if it were either. Furthermore, animals and infants who are nonverbal perceive shape much as we do. I am proposing that a process analogous to such a description does take place and that it is not only based on the internal geometry of a figure but also takes into account the location of the figure's top, bottom and sides. In such a description orientation is therefore a major factor in the shape that is finally perceived.

From experiments I have done in collaboration with Phyllis Olshansky it appears that certain shifts in orientation have a marked effect on perceived shape. In particular, creating symmetry around a vertical axis

where no symmetry had existed before (or vice versa), shifting the long axis from vertical to horizontal (or vice versa) and changing the bottom of a figure from a broad horizontal base to a pointed angle (or vice versa) seemed to have a strong effect on perceived shape. Such changes of shape can result from only a moderate angular change of orientation, say 45 or 90 degrees. Interestingly enough, inversions or rotations of 180 degrees often have only a slight effect on perceived shape, perhaps because such changes will usually not alter perceived symmetry or the perceived orientation of the long axis of the figure.

There is one kind of orientation change that has virtually no effect on perceived shape: a mirror-image reversal. This is particularly true for the novel figures we used in our experiments. How can this be explained? It seems that although the "sides" of visual space are essentially interchangeable, the up-and-down directions in the environment are not. "Up" and "down" are distinctly different directions in the world we live in. Thus a figure can be said to have three main perceptual boundaries: top, bottom and sides. As a result the description of a figure will not be much affected by whether a certain feature is on the left side or the right. Young children and animals have great difficulty learning to discriminate between a figure and its mirror image, but they can easily distinguish between a figure and its inverted counterpart.

Related to this analysis is a fact observed by Mach and tested by Erich Goldmeier: A figure that is symmetrical around one axis will generally appear to be symmetrical only if that axis is vertical. Robin Leaman and I have demonstrated that it is the perceived vertical axis of the figure and not the vertical axis of the figure's retinal image that produces this effect. An observer who tilts his head will continue to perceive a figure as being symmetrical if that figure is symmetrical around an environmental vertical axis. This suggests that perceived symmetry results only when the two equivalent halves of a figure are located on the two equivalent sides of perceptual space.

If, as I have suggested, the description of a figure is based on the location of its top, bottom and sides, the question arises: How are these directions assigned in a figure? One might suppose that the top of a figure is ordinarily the area uppermost in relation to the ceiling, the sky or the top of a page. In a dark room an observer may have to rely on his sense of gravity to inform him which way is up.

Numerous experiments by psychologists have confirmed that there are indeed two major sources of information for perceiving the vertical and the horizontal: gravity (as it is sensed by the vestibular apparatus in the inner ear, by the pressure of the ground on the body and by feedback from the muscles) and information from the scene itself. We have been able to demonstrate that either can affect the perceived shape of a figure.

A luminous figure in a dark room will not be recognized readily when it is rotated to a new orientation even if the observer is tilted by exactly the same amount. Here the only source of information about directions in space is gravity. In a lighted room an observer will often fail to recognize a figure when he and the figure are upright but the room is tilted. The tilted room creates a strong impression of where the up-down axis should be, and this leads to an incorrect attribution of the top and bottom of the figure [see "The Perception of the Upright," by Herman A. Witkin; *Scientific American*, February, 1959].

Merely informing an observer that a figure is tilted will often enable him to perceive the figure correctly. This may explain why some readers will not perceive certain of the rotated figures shown here as being strange or different. The converse situation, misinforming an observer about the figures, produces impressive results. If a subject is told that the top of a figure he is about to see is somewhere other than in the region uppermost in the environment, he is likely not to recognize the figure when it is presented with the orientation in which he first saw it. The figure is not disoriented and the observer incorrectly assigns the directions top, bottom and sides on the basis of instructions.

Since such knowledge about orientation will enable the observer to shift the directions he assigns to a figure, and since it is this assignment that affects the perception of shape, it is absolutely essential to employ naïve subjects in perception experiments involving orientation. That is, the subject must not realize that the experiment is concerned with figural orientation, so that he does not examine the figures with the intent of finding the regions that had been top, bottom and sides in previous viewings of it. There are, however, some figures that seem to have intrinsic orientation in that regardless of how they are presented a certain region will be perceived as the top [fig. 9.8]. It is therefore difficult or impossible to adversely affect the recognition of such figures by disorienting them.

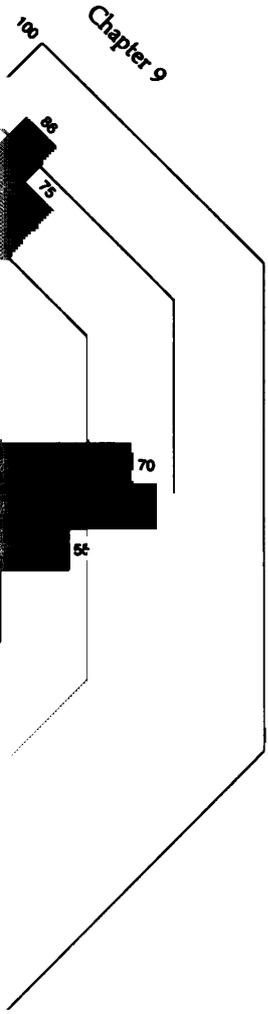
In the absence of other clues a subject will assign top-bottom coordinates according to his subjective or egocentric reference system. Consider a figure drawn on a circular sheet of paper that is lying on the ground. Neither gravity nor visual clues indicate where the top and bottom are. Nevertheless, an observer will assign a top to that region of the figure which is uppermost with respect to his egocentric coordinate reference system. The vertical axis of the figure is seen as being aligned with the long axis of the observer's head and body. The upward direction corresponds to the position of his head. We have been able to demonstrate that such assignment of direction has the same effect on the recognition that other bases of assigning direction do. A figure first seen in one ori-

entation on the circular sheet will generally not be recognized if its ego-centric orientation is altered.

Now we come to an observation that seems to be at variance with much of what I have described. When a person lies on his side in bed to read, he does not hold the book upright (in the environmental sense) but tilts it. If the book is not tilted, the retinal image is disoriented and reading is quite difficult. Similarly, if a reader views printed matter or photographs of faces that are environmentally upright with his head between his legs, they will be just as difficult to recognize as they are when they are upside down and the viewer's head is upright. The upright pictures, however, are still perceived as being upright even when the viewer's head is inverted. Conversely, if the pictures are upside down in the environment and are viewed with the head inverted between the legs, there is no difficulty in recognizing them. Yet the observer perceives the pictures as being inverted. Therefore in these cases it is the orientation of the retinal image and not the environmental assignment of direction that seems to be responsible for recognition or failure of recognition.

Experiments with ambiguous figures conducted by Robert Thouless, G. Kanizsa and G. Tampiari support the notion that retinal orientation plays a role in recognition of a figure [see fig. 9.16]. Moreover, as George Steinfeld and I have demonstrated, the recognition of upright words and faces falls off in direct proportion to the degree of body tilt [see fig. 9.11]. With such visual material recognition is an inverse function of the degree of disorientation of the retinal image. As we have seen, the relation between degree of disorientation and recognizability does not hold in cases where the assignment of direction has been altered. In such cases the greatest effect is not with a 180-degree change but with a 45- or 90-degree change.

The results of all these experiments have led me to conclude that there are two distinct factors involved in the perception of disoriented figures: an assignment-of-direction factor and a retinal factor. I believe that when we view a figure with our head tilted, we automatically compensate for the tilt in much the same way that we compensate for the size of distant objects. An object at a moderate distance from us does not appear small in spite of the fact that its retinal image is much smaller than it is when the object is close by. This effect usually is explained by saying that the information supplied by the retinal image is somehow corrected by allowing for the distance of the object from us. Similarly, when a vertical luminous line in a dark room is viewed by a tilted observer, it will still look vertical or almost vertical in spite of the fact that the retinal image in the observer's eye is tilted. Thus the tilt of the body must be taken into account by the perceptual system. The tilted retinal image is then



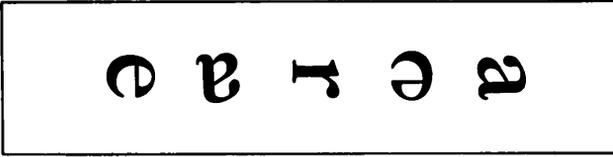


Figure 9.12

Single letter that is tilted can be easily identified once it is realized how it is oriented. A strangeness in its appearance, however, remains because the percept arising from the uncorrected retinal image continues to exist simultaneously with the corrected percept.

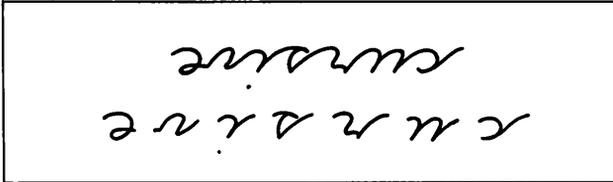


Figure 9.13

Inverted longhand writing is difficult to decipher because many inverted units resemble written upright letters. For example, an inverted *u* will look like an *n* and an inverted *c* like an *s*. Moreover, the connection between letters leads to uncertainty about where a letter begins and ends. Several inverted units can be grouped together and misperceived as an upright letter. Separating the inverted letters makes them easier to decipher.



Figure 9.14

Inverted facial features are difficult to interpret because while attention is focused on correcting one feature other features remain uncorrected. For example, one might succeed in correcting the eyes shown here so that they are perceived as gazing downward and leftward, but at that very moment the mouth is uncorrected and expresses sorrow rather than pleasure. Conversely, one might correct the mouth and misperceive the eyes.

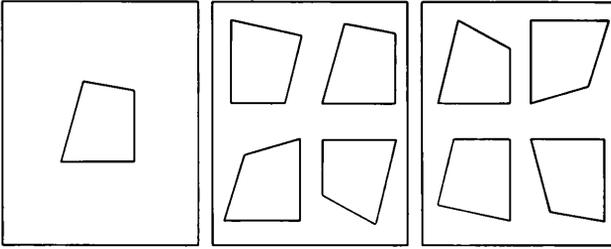


Figure 9.15

Multiple items were found to have an adverse effect on recognition of even simple figures. Subjects sitting upright viewed the target (*left*). Then they were briefly shown test cards, some of which contained the target figure (*middle*) and some of which did not (*right*). The subjects were to indicate when they saw a figure that was identical with the target figure. Half of the test cards were viewed with the head upright and half with the head inverted. Recognition was poor when inverted subjects viewed the test cards. In other experiments with a single test figure head inversion did not significantly affect recognition.

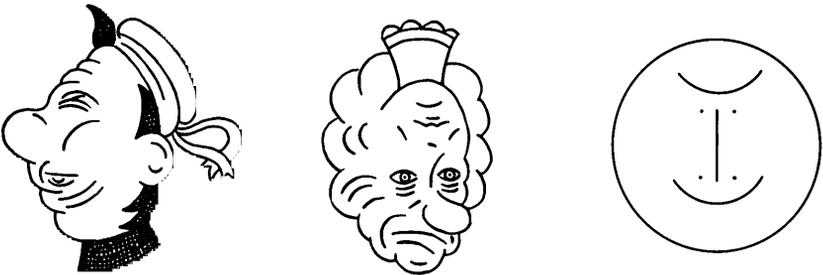


Figure 9.16

Ambiguous faces are perceived differently when their images on the retina of the observer are inverted. If you hold the illustration upright and view it from between your legs with your head inverted, the alternative faces will be perceived even though they are upside down in terms of the environment. The same effect occurs when the illustration is inverted and viewed from an upright position. Such tests provide evidence that figures such as faces are recognized on the basis of their upright retinal orientation.

corrected, with the result that the line is perceived as being vertical. Just as the correction for size at a distance is called size constancy, so can correction for the vertical be called orientation constancy.

When we view an upright figure with our head tilted, before we have made any correction, we begin with the information provided by an image of the figure in a particular retinal orientation. The first thing that must happen is that the perceptual system processes the retinal image on the basis of an egocentrically assigned top, bottom and sides, perhaps because of a primitive sense of orientation derived from retinal orienta-

tion. For example, when we view an upright square with our head tilted, which yields a diamondlike retinal image, we may perceive a diamond for a fleeting moment before the correction goes into operation. Head orientation is then automatically taken into account to correct the perception. Thus the true top of the figure is seen to be one of the sides of the square rather than a corner. The figure is then "described" correctly as one whose sides are horizontal and vertical in the environment, in short as a "square." This correction is made quickly and usually without effort. In order to describe a figure the viewer probably must visualize or imagine it in terms of its true top, bottom and sides rather than in terms of its retinal top, bottom and sides.

If the figure is relatively simple, the correction is not too difficult to achieve. If we view an upright letter with our head tilted, we recognize it easily; it is of interest, however, that there is still something strange about it. I believe the dual aspect of the perception of orientation is responsible for this strangeness. There is an uncorrected perception of the letter based on its retinal-egocentric orientation and a corrected perception of it based on its environmental orientation. The first perception produces an unfamiliar shape, which accounts for the strange appearance of the letter in spite of its subsequent recognition. In our experiments many of the figures we employed were structurally speaking equivalent to letters, and in some cases we actually used letters from unfamiliar alphabets.

With a more complex figure, such as an inverted word or an upright word viewed by an inverted observer, the corrective mechanism may be entirely overtaxed. Each letter of the word must be corrected separately, and the corrective mechanism apparently cannot cope simultaneously with multiple components. It is true that if an observer is given enough time, an inverted word can be deciphered, but it will never look the same as it does when it is upright. While one letter is being corrected the others continue to be perceived in their uncorrected form. There is a further difficulty: letter order is crucial for word recognition, and inverting a word reverses the normal left-to-right order.

The recognition of inverted longhand writing is even more difficult. When such writing is turned upside down, many of the inverted "units" strongly resemble normal upright longhand letters. Moreover, since the letters are connected, it is difficult to tell where one letter ends and another begins. Separating the letters of the inverted word makes recognition easier. Even so, it is all too easy to confuse a *u* and an *n*. This type of confusion is also encountered with certain printed letters, namely, *b* and *q*, *d* and *p* and *n* and *u*, although not as frequently. In other words, if a figure is recognized on the basis of its upright retinal-egocentric

orientation, this may tend to stabilize the perception and block the correction process. The dominance of the retinally upright faces in figure 9.16 probably is an effect of just this kind.

There may be a similar overtaxing of the corrective mechanism when we view an inverted face. It may be that the face contains a number of features each of which must be properly perceived if the whole is to be recognized [see "The Recognition of Faces," by Leon D. Harmon; *Scientific American*, November, 1973]. While attention is focused on correcting one feature, say the mouth, other features remain uncorrected and continue to be perceived on the basis of the image they form on the retina. Of course, the relation of features is also important in the recognition of a face, but here too there are a great number of such relations and the corrective mechanism may again be overtaxed.

Charles C. Bebbler, Douglas Blewett and I conducted an experiment to test the hypothesis that it is the presence of multiple components that creates the difficulty of correcting figures. Subjects were briefly shown a quadrilateral figure and asked to study it. They viewed the target figure with their head upright. Then they were shown a series of test cards each of which had four quadrilateral figures. The test cards were viewed for one second, and the subjects were required to indicate if the target figure was on the card.

The subjects understood that they were to respond affirmatively only when they saw a figure that was identical with the target figure both in shape and in orientation. (Some of the test figures were similar to the target figure but were rotated by 180 degrees.) Half of the test cards were seen with the subject's head upright and half with the subject's head inverted. It was assumed that the subject would not be able to correct all four test figures in the brief time that was allowed him while he was viewing them with his head down. He had to perceive just as many units in the same brief time while he was viewing them with his head upright, but he did not have to correct any of the units. We expected that target figures would often not be recognized and that incorrect figures would be mistakenly identified as the target when the subjects viewed the test cards with their heads inverted.

The results bore out our prediction. When multiple components have to be corrected, retinal disorientation has an adverse effect on recognition. The observer responded to twice as many test cards correctly when he was upright than he did when he was inverted.

As I have noted, when we look at figures that are difficult to recognize when they are retinally disoriented, the difficulty increases as the degree of disorientation increases. Why this happens may also be related to the nature of the correction process. I suggested that the observer must suppress the retinally (egocentrically) upright percept and substitute a cor-

rected percept. To do this, however, he must visualize or imagine how the figure would look if it were rotated until it was upright with respect to himself or, what amounts to the same thing, how it would look if he rotated himself into alignment with the figure. The process of mental rotation requires visualizing the entire sequence of angular change, and therefore the greater the angular change, the greater the difficulty.

As every parent knows, children between the ages of two and five seem to be quite indifferent to how a picture is oriented. They often hold a book upside down and seem not at all disturbed by it. On the basis of such observations and the results of some early experiments, many psychologists concluded that the orientation of a figure did not enter into its recognition by young children. More recent laboratory experiments, however, do not confirm the fact that children recognize figures equally well in any orientation. They have as much difficulty as, or more difficulty than, adults in recognizing previously seen figures when the figure is shown in a new orientation. Why then do young children often spontaneously look at pictures upside down in everyday situations? Perhaps they have not yet learned to pay attention to orientation, and do not realize that their recognition would improve if they did so. When children learn to read after the age of six, they are forced to pay attention to orientation because certain letters differ only in their orientation.

In summary, the central fact we have learned about orientation is that the perceived shape of a figure is not simply a function of its internal geometry. The perceived shape is also very much a function of the up, down and side directions we assign to the figure. If there is a change in the assigned directions, the figure will take on a different perceptual shape. I have speculated that the change in perceived shape is based on a new "description" of the figure by the perceptual system. The directions assigned are based on information of various kinds about where the top, bottom and sides of a figure are and usually do not depend on the retinal orientation of the image of the figure. When the image is not retinally upright, a process of correction is necessary in order to arrive at the correct description, and this correction is difficult or impossible to achieve in the case of visual material that has multiple components.

All of this implies that form perception in general is based to a much greater extent on cognitive processes than any current theory maintains. A prevailing view among psychologists and sensory physiologists is that form perception can be reduced to the perception of contours and that contour perception in turn can be reduced to abrupt differences in light intensity that cause certain neural units in the retina and brain to fire. If this is true, then perceiving form results from the specific concatenation of perceived contours. Although the work I have described does not deny

the possible importance of contour detection as a basis of form perception, it does suggest that such an explanation is far from sufficient, and that the perception of form depends on certain mental processes such as description and correction. These processes in turn are necessary to account for the further step of recognition of a figure. A physically unchanged retinal image often will not lead to recognition if there has been a shift in the assigned directions. Conversely, if there has been no shift in the assigned directions, even a very different retinal image will still allow recognition.

This excerpt from

Indirect Perception.
Irvin Rock.
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