

The information available in pictures

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THE INFORMATION AVAILABLE IN PICTURES

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Abstract - The author reviews two current conflicting theories of what a picture is: (1) that it consists of a sheaf of light rays coming to a station point or perceiver, each corresponding to a spot of color on the picture surface and hence that the picture can stand for a real object or scene insofar as the rays from the picture are the same as the rays from the real object; (2) that it consists of a set of symbols, more or less like words, and the perceiver must learn to 'read' it. According to the first theory, a child can perceive an object in a picture as soon as it can perceive a real object; according to the second one, the child must learn to 'read' the picture much as it, learns to read written speech.

He points out the fallacies of both theories, shows that they cannot be combined and suggests a new theory based on the radical assumption that light can convey information about the world and, hence, that the phenomenal world does not have to be constructed by the mind (or the brain) out of meaningless data. This theory makes it possible to distinguish between the pictorially mediated perception of the features of a world and the direct perception of the features of the surroundings and yet to understand that there is common information for the features they have in common.

His theory accounts for the difference between verbal and visual thinking. Visual thinking is freer and less stereotyped than verbal thinking; there is no vocabulary of picturing as there is of saying. As every artist knows, there are thoughts that can be visualized without being verbalized.

Underlying all the discussions of representation there are currently two conflicting theories of what a picture is. The first theory assumes that it consists of a sheaf of light rays coming to a station point or perceiver, each corresponding to a spot of color on the picture surface. The second theory assumes that it consists of a set of symbols, more or less like words, and that a painting is comparable to a written text. On the first theory, a picture can represent a real object or scene insofar as the light rays from the picture are the same as the light rays from the original. On the second theory, a picture can stand for a real object or scene insofar as the language of pictures is understood. The second theory says that one has to learn to 'read' a picture, much as the child has to read written speech, but the first theory denies this and asserts that as soon as a child can perceive an object directly he can perceive it in a picture.

One might suppose that these theories as stated are merely extremes, and that they can somehow

be combined. But attempts to reconcile them have not been successful, or at least I find them unsuccessful and I have come to believe instead that both theories are wrong. We need a new theory of what a picture is. I will try to suggest later what it might be but first let us get clear about the two opposing positions, what the force of the argument is in each case and why in the last analysis they fail.

THE POINT-PROJECTION THEORY OF PICTORIAL INFORMATION

By the eighteenth century the technique of perspective representation, discovered by painters in the Renaissance, had matured along with the developing science of optics (cf. Fig. 1). An English mathematician could assert in 1715 that in order to produce a perfect painting of objects, 'the Light ought to come from the Picture to the spectator's Eye in the very same manner as it would do from the Objects themselves' [1]. It would be as if the light came through a window, to be sure, corresponding to the frame of the picture but if each light ray from a spot of pigment on the canvas were the same in wavelength and intensity as each light ray from a spot on the front face of the object coming to the eye through the window, then the two bundles of light rays would correspond and the representation of the object would be complete. At the time of this assertion, Isaac Newton's treatise on *Optics* had been published and it was widely read.

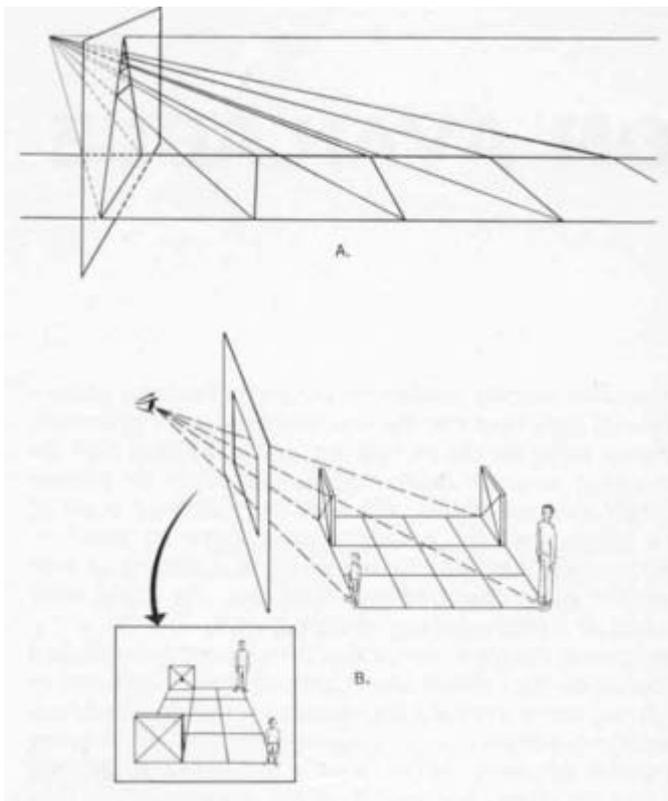


Fig. 1. The principles of pictorial representation.

The projection on a picture-plane of a regular pavement extending into the distance is shown in A. The main laws of linear perspective can be observed, especially the vanishing point at the horizon. The projection of a scene on a window of the picture-plane is shown in B. Note the angular size relations and the transformations of square-into-trapezoid. Straight edges are projected as

straight lines in the picture (straightness is invariant). The perspective of surface texture is not shown, only what are called outlines. In both cases, note that it is the optic array that is the stimulus, not the image. A. (From J. J. Gibson, The Perception of the Visual World, Houghton Mifflin, 1950. B. After Julian E. Hochberg, Perception, © 1964. Adapted by permission of Prentice Hall, Inc., Englewood Cliffs, N.J.)

This theory of the perfect picture seemed to fit [27] exactly with the theory of visual perception based on the retinal image that was developing at the same time. Newton asserted with confidence that:

'the Light which comes from the several points of the Object is so refracted as to ... paint the Picture of the object upon that skin called the *Retina*...And these Pictures, propagated by motion along the Fibres of the Optick Nerves into the Brain, are the cause of Vision. For accordingly as these Pictures are perfect or imperfect, the Object is seen perfectly or imperfectly' [2].

The theory of point-projection (along with the theory of the projected retinal image) has proved to be very powerful over the centuries. Light is, in fact, projective; one can project shadows or transparent pictures and the abstract notion of point-to-point correspondence is part of the branch of mathematics called projective geometry. Fifteen years ago I wrote an essay called 'A Theory of Pictorial Perception' [3] in the effort to make it explicit for students of visual education. I defined the fidelity of a picture by analogy with the fidelity of a sound recording, assuming that it could go from a maximum to no fidelity at all. A faithful picture *was a delimited surface so processed that it yielded a sheaf of light-rays to a given point which is the same as would be the sheaf of rays from the original scene to a given point, that is, when the adjacent order of the points of color in the crosssection of one corresponded to the adjacent order in the cross-section of the other* [4]. I should have added, *and when the forms in the one cross-section are congruent with the forms in the other*. This is essentially the same as the eighteenth-century definition quoted above. I did hedge it somewhat by suggesting that the *variations* in the adjacent light energy across one array might correspond with the *variations* across the other, thus introducing the notion of corresponding contrasts or relations instead of corresponding points of light. I was aware of the fact that the light intensities from a world range over extremes that cannot possibly be matched by the light intensities from a picture. I did take some account of the paradox that if another station point were chosen for the light-rays than the uniquely proper one, the picture would no longer be faithful since the forms would no longer be congruent. In short, I had some idea of the limitations of the definition but not enough to reject it.

I amended this definition considerably in a later paper entitled: *Pictures, Perspective, and Perception* [5] but I still retained the notion of a sheaf of light rays and did not discard the notion of fidelity in terms of rays. The new definition I will propose is based on ecological optics, not geometrical optics, and it transcends the concept of light rays. Most of what was said about pictures in 1960, however, I will still stand by. A series of studies over a period of 15 years has been carried out - at Cornell on pictorial perception by Gibson [6], Ryan and Schwartz [7], Smith and Gruber [8], Smith and Smith [9], Hochberg [10], Hochberg and Brooks [11] and most recently Kennedy [12].

In the latter part of my 1954 essay, there was an admission which actually invalidated the point-by-point projection theory, although I did not realize it at the time. I said that a picture actually had many different dimensions of fidelity to an object, not just one, and that lines or outlines in a handmade picture could faithfully represent the edges and corners of the surfaces of the world,

although, of course, the lines could not represent their colors or textures. But this actually gives the whole thing away; the definition can only apply to a painting or photograph, not to a line drawing. There is no point-to-point correspondence of brightness or color between the optic array from a line drawing and the optic array from the object represented. There is some sort of correspondence but it must be of a very different kind than the one defined. In order to describe this relational or higher-order correspondence, we need a new optics not limited to rays of light.

Finally, there is still another objection to the [28] point-projection theory, with its definition of fidelity in terms of light-rays and the forms they project on a plane. It does not apply to the caricature. The cartoonist's drawing of a man is not even a faithful projection of the shape of his features and his body. It does not represent his curves and contours. We say that it is distorted, which can only mean that the man represented is a *deformed or distorted* man. But this statement is somehow not right. The caricature may be faithful to those features of the man that distinguish him from all other men and thus may truly represent him in a higher sense of the term. It may correspond to him in the sense of being uniquely specific to him more so than a projective drawing or a photographic portrait would be. And this is a compelling objection to the whole theory that pictorial information can be reduced to light rays.

One might try to salvage part of the theory by supposing that distortion in caricatures is exceptional; it is not actually a kind of representation but a kind of graphic symbolism like the using of words. I was tempted by this compromise in 1954 [4]. I assumed that when an artist sacrificed projective fidelity the only justification was that he adopted graphic conventions, that is, codes which had to be agreed upon by all. I assumed that the only two possible kinds of specification were by *projection* or by *convention*. A caricature, therefore, was a mixture of the two. But this was only to combine incompatible notions. A caricature is *not* a mixture of optical projection and symbolic distortion but something different from either one. In the end, I will suggest that it is an effort at displaying relevant information.

Why, then, is the point-projection theory being considered so plausible? It is, first of all, consistent with physical optics and with the doctrine of visual sensations that seems to follow from it. This says that the pattern of light entering the eye consists of irreducible bits of color and brightness and that these are the *only* information the eye gets. These spots cannot specify the objects and surfaces from which the light comes; they can only specify sensations of color and brightness. All the rest of perception is a matter of interpretation. For example, the distance of an object, the third dimension of space, is either a matter of learning what the clues for distance are or else of having an unlearned intuition about them. But interpretation depends on sensations. Hence a picture that reconstitutes or represents the mosaic of color sensations from an external scene will arouse the same process of perception that the external scene would. This is the argument and it seems to be very convincing.

The force of the argument comes in part from the evidence said to show that a faithful picture can fool the observer into the feeling that he is looking at a reality instead of just a picture. Since two identical retinal images will yield the same perception, according to the theory, they should yield the same feeling of reality. This is the 'illusion of reality' that has fascinated men over the ages. It is represented by the legend of Pygmalion, for whom the image and the reality were identical. It is the theme of a comprehensive and eloquent book by E. H. Gombrich [13]. Nearly everyone has been deceived, at one time or another, into taking a picture for the real thing. So we tend to accept the conclusion that a picture can be, as a limit, indistinguishable from the thing pictured. But this is a vague and slippery statement, as will be shown later. If it means that the perception of

something pictured can gradually *become* the direct perception of that something, then it is not true.

THE SYMBOL THEORY OF PICTORIAL INFORMATION

Artists themselves have never cared much for this point-projection theory of pictorial representation for it seemed to prescribe and constrain what they should do. Painters, critics and historians of art have rebelled against the whole concept of the perfect picture and the faithful image. But since the concept had the powerful support of optics and the physiology of the eye, the justification of the rebellion was not easy.

Twenty-five years ago, Kepes wrote a book called the *Language of Vision* [14] and recently Goodman has written another book called *Languages of Art* [15]. I think I understand what these two writers are saying. They are suggesting that a picture is composed of symbols, that the clearest examples of symbols are the letters and words of a language and that, therefore, one can learn to read a picture as the child learns to read English.

Kepes maintained that the components of a picture were not spots of sensation but something else:

'Just as the letters of the alphabet can be put together in innumerable ways to form words which convey meanings, so the optical measures and qualities can be brought together in innumerable ways, and each particular relationship generates a different sensation of space. The variations to be achieved are endless' [16].

He gave illustrations of what he called this space language in his book (cf. Fig. 2). The light rays as such, he said 'are only a haphazard chaotic panorama of mobile independent light-happenings' [17]. This point, that light rays are each independent of every other, had been made by the Gestalt theorists.

Similarly, if much more elaborately, Goodman stresses the analogy between pictorial representation and verbal description. 'Representations, then, are pictures that function in somewhat the same way as descriptions. Just as objects are classified by means of, or under various verbal labels, so also are objects classified by or under various pictorial labels' [18]. He accepts the theory that an act of perception is essentially an act of [29] classification by the observer, assuming that classes have to be imposed on the data.

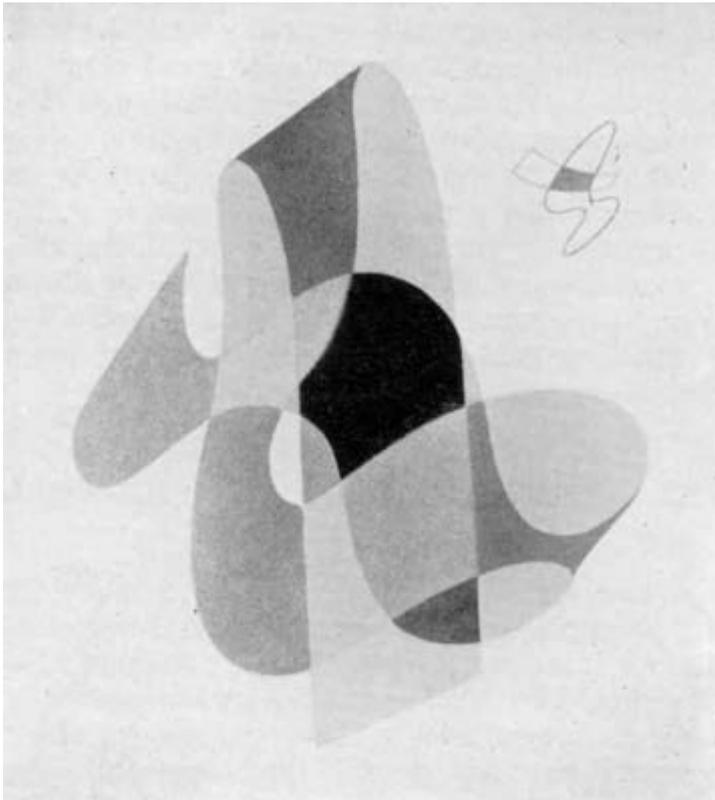


Fig. 2. 'Study of Transparency' by Clifford Eitel, from G. Kepes *Language of Vision*, Paul Theobald and Co., 1944. Reprinted with permission of the publisher.

Now if painting is a language, then just as a new language can be invented (an artificial language like Esperanto, for instance) and can be learned by mastering its vocabulary and grammar, so a new mode of visual perception can be invented by painters and this can be learned by all of us if we succeed in mastering its elements. This revolutionary belief is, indeed, what motivates a good many modern painters. They intend not merely to educate our visual perception of the world but to give us a radically different kind of perception and make us discard the old kind. Arnheim, for example, in *Art and Visual Perception* asserts boldly that only a kind of 'shift of level' is needed 'to make the Picassos, the Braques, or the Klees look exactly like the things they represent' [19]. These paintings do not now represent things for us, he seems to admit, but they will come to do so. Is this theory correct? A crucial issue in the debate is whether or not the use of perspective in painting is a *convention*. The assertion that it is was made long ago by the art historian Irwin Panofsky [20] and it has been upheld by Kepes [14], by Arnheim [19] (1954) and by Goodman [15]. I once maintained in opposition, that:

'it does not seem reasonable to assert that the use of perspective in paintings is merely a convention to be used or discarded by the painter as he chooses ... when the artist transcribes what he sees upon a two-dimensional surface, he uses perspective geometry, of necessity' [21].

But Goodman disagrees:

'In diametric contradiction to what Gibson says, the artist who wants to produce a spatial representation that the present-day Western eye will accept as faithful must defy the "laws of geometry" [22].

The main contribution of Goodman's book is not reflected in these quotations. When he is discussing pictures, especially paintings, he accepts the analogy with language but he also tries to work out the principles of what he calls *notation* and to apply them to all the various arts. This attempt does not seem to bear directly on the issue of what a picture is; he is clarifying a different problem, not here considered.

The controversy is interesting and important but it is plagued by confusion and misunderstanding. The disrespects of geometry appeal to so-called inverse perspective in painting. Here is Kepes speaking, from the *Language of Vision*:

'Chinese and Japanese painters assign to linear perspective a diametrically opposite role from that given it by Western painters. In their system parallel lines converge as they approach the spectator. They open up the space instead of closing it' [23].

But let us be clear about this. It is certainly not true that parallel lines in the world (actually the edges of surfaces) converge as lines on a projection plane as the external edges approach the spectator; the lines must *diverge* as the edges become closer. No rule or canon of inverse perspective could possibly be *systematic*, that is, it could not be consistently applied in the practice of projecting a layout of surfaces on a picture-plane. I do not know why Oriental painters (and Medieval painters and sometimes children) often represent the edges of table-tops and floors as diverging upward on the picture surface instead of converging upwards but I know that they do not have a *system*. I suspect that this so-called inversion of linear perspective was quite unintentional and that the explanation is not simple.

What if anything, then, *is* conventional in a representative picture, if perspective is not - what is arbitrary or prescribed? Only the rules for observing the picture surface, which are as follows: it should be seen with one eye, it should be upright and perpendicular to the line of sight instead of slanted and its distance must be just such that the visual solid angle from the picture is the same as would be the visual solid angle from the thing pictured. These rules, note, are highly restrictive and cannot be enforced on the spectator. But when they are not followed, there results a little-understood phenomenon vaguely called 'perspective distortion'. There is also another prescription to enhance the illusion of reality that is never followed in practice: there should be an aperture in front of the eye hiding everything but the picture itself.

The *system* of perspective projection, its optical [30] geometry, is a very pretty thing. But it has to be distinguished from the *practice* of perspective. Almost from the discovery of the system, the practice has proved to be less than satisfactory to painters. It was unsatisfactory for the very good reason that people cannot be made to look at a picture in the way prescribed. The system had to be compromised for the spectator's benefit in *ad hoc* ways, for example, to minimize perspective distortion. Painters and sympathetic critics put the blame on the system, not distinguishing it from the practice of perspective. Most of them did not understand or care about the abstract elegance of perspective geometry. For example, they confused the habit of putting a vanishing point in the center of the picture, which is a matter of composition, and, therefore, to be freely chosen, with the system of perspective projection as such. And thus, if I am right, when artists stopped using perspective entirely as a guide to painting, they may have had good reason but the reason given should not have been that perspective is a convention. For they might be interpreted to mean that the science of optics is itself a convention. They might be saying that optics is not just ill-formulated for the purpose of understanding pictorial perception but it can never be formulated for

that purpose. The first statement I believe. The second I deny, for I have some ideas about how to reformulate optics.

A NEW THEORY OF PICTORIAL INFORMATION

If a picture is neither the source of a sheaf of different light rays each corresponding to a spot on the surface, on the one hand, nor a layout of graphic symbols like writing, on the other, what is it? I suggest that it is a display of optical information and that optical information does not consist of either spots of color or conventional figures with assigned meanings. It comes in an optic array, to be sure, but the array is composed of a hierarchy of nested units, not of rays. Information is contrasted with energy. There has to be enough stimulus energy in an optic array to excite the retinal receptors but the stimulus information is what counts for perception. And stimulus information is invariant under all sorts of changes in stimulus energy. Here is a formal definition. *A picture is a surface so treated that a delimited optic array to a point of observation is made available that contains the same kind of information that is found in the ambient optic arrays of an ordinary environment.* This definition covers both the photograph and the caricature. It admits that a photographic color transparency can provide an eye with *almost* the same brightness and color contrasts that the cone of light intercepted by the camera provided. The *relations* of luminous intensity and spectral composition of the stimulus energies in the two arrays are in sufficient correspondence to make the low-order stimulus information very nearly the same. But the definition is broad enough also to admit the case of a caricature, where the contrasts of luminous energy are quite different and even the forms are different but where the high-order information to specify a particular person is common to both arrays. In short the optic array from a picture and the optic array from a world can provide the same information without providing the same stimulation. Hence, an artist can capture the *information* about something without replicating its *sensations*.

The above definition is based on a new theory of perception as well as a new formulation of optics. It assumes that two perceptions can be the same without their accompanying sensations being the same. It implies that visual sensations are not necessary for visual perception, strange as this may seem. Perception is based on the pickup of information, not on the arousal of sensation, and the two processes are distinct. Having sensations is at most only an accompaniment of perceiving, not a prerequisite of perceiving. Visual sensations are a sort of luxury incidental to the serious business of perceiving the world. I have argued all this, of course, in *The Senses Considered as Perceptual Systems* [24].

The heart of the theory is the concept of optical information. Information consists of *invariants*, in the mathematical sense, of the structure of an optic array. Let us consider the information for the perception of an object in the environment. When one sees an object one does *not* ordinarily see its front surface, in perspective. One sees the whole of it, the back as well as the front. In a sense all of its aspects are present in the experience. It is an object in the phenomenal visual *world*, not a form in the phenomenal visual *field* [25]. How can this be so? The basis of this direct perception is not the form sensations, or even the remembered sequence of these forms, but the *formless and timeless invariants that specify the distinctive features of the object*. These are the information for perception.

But what about the indirect perceiving of an object when one is presented with a picture of it? The picture, we have always understood, is only one of an infinite family of perspectives of the object, frozen in time. But we can now understand that an *informative* picture contains the same kind of

timeless invariants that a sequence of perspectives contains. If it does not provide the eye with these invariants, it is not a good picture of the object (for example, if it is not depicted from a favorable point of view). The fact is that even when one sees a pictured object one ordinarily does not see its front surface only but the whole of it. This is an unsolved paradox for sensation-based theories of perception but it follows immediately from the present theory.

The timeless invariants become more obvious over time, it is true, in a motion picture as compared with a still picture but some of them at least are still present in the latter. When one walks around an object, or sees it rotating, its optic array under [31] goes perspective transformation and the whole family of perspectives is available to the eye, so that the invariants are easy to see and the single perspectives are not; in fact, it is then almost impossible to see a single perspective. This is the normal way of seeing an object. On the other hand, when one holds still it is easier to see the single perspective than when one moves around. But this is not the normal way of seeing an object.

THE NAIVE ATTITUDE AND THE PERSPECTIVE ATTITUDE

There is evidence to suggest that animals and young children do not notice the aspects of an object or the perspectives of the environment. (An aspect or perspective is an *appearance* at a single stationary point of view.) The world does not appear as a frozen patchwork of flat colors confined by the boundaries of the temporary field of view [26]. What they notice is the set of invariant distinctive features of objects and the rigid layout of environmental surfaces. They see the non-change underlying the change. This is the naive attitude. I also believe that our primitive ancestors, before the discovery of pictorial representation by the cave painters, had never noticed the aspects of objects and the perspectives of the environment. They could only take the naive attitude toward the world. Why should the Ice Age hunters have noticed that a mammoth had a different *appearance* from the front, the side, the rear and above? Why should they have observed that a thing appears to get smaller as it gets farther away? What use would there be to have paid any attention to linear perspective, and vanishing points and the optical horizon? But as our ancestors began increasingly to make pictures they began to notice these appearances. They began to see aspects, perspectives, in short *forms*. The man who painted the mammoth on the cave wall *had* to notice and remember one aspect (usually the side view) since the necessity of making tracings on a flat surface required it. And so it was, I think, that some men began sometimes to take the perspective attitude in viewing the environment. They began to be able to see the world as a picture [27]. But they had to learn to do so.

The modern child also has to learn it. He is surrounded by pictures and is encouraged by his parents to convert his scribbles into representations as soon as possible. But this is not easy, for contrary to orthodox theory, he does not experience his retinal image. And so, in learning to draw, he has to learn to pay attention to the projected forms as distinguished from the formless invariants. If the young child experienced his retinal image he should not *have* to learn to draw. The 'innocent eye', far from registering points of color or even patches of color, picks up invariant relations [28].

If I am right, then, the modern adult can adopt a naive attitude or a perspective attitude. He can attend to visible things or to visual sensations. And it is much the same when he looks at a picture as when he looks at the world. He can notice only the information for the perception of what is represented or he can pay attention to the picture as such, to the medium, the technique, the style, the composition, the surface and the way the surface has been treated. It is possible of course to shift from one attitude to the other and some pictures fairly compel us to go back and forth from the virtual object that is *in* the picture to the *real* object that *is* the picture. It is

possible to combine these attitudes in various ways.

This duality, I suggest, is the essence of representation. Ordinarily one can perceive both the picture as a thing and the thing pictured. There is optical information to specify the surface as such and, in the same array, information to specify a quite different layout of surfaces. There are thus two concurrent levels of surface perception and two corresponding levels of depth or space perception. One is the space in which the picture lies and the other is the space in which the objects pictured lie. I have made experiments to verify this duality. If you place a photomural on the wall of a room representing (say) a road and trees, and if you then put an observer at the proper station point, you will find that he can 'perceive' the distance of one of the trees and its height. He confidently estimates that it is a hundred paces away and twenty feet high, with about the same accuracy as when he is actually standing on the road that was photographed. But he can also, on request, perceive and estimate the distance and the height of the *picture*. This object is seen to be three paces away and four feet high. The distance and size of the tree and the picture are not commensurate, for they are not in the same space. The space of the road and the space of the room are not continuous with one another.

When you come to analyse the optic array from the room-and-picture, you find that it contains information for both the perception of the room-space and the perception of the picture-space. Neglecting binocular disparity and the focussing of the lens, the optical texture is present to specify both the surface of the road and the surface of the photograph, and the *gradients* of texture are present to specify both the distance of the tree and the distance of the wall.

BUT WHAT ABOUT THE ILLUSION OF REALITY?

The point-projection theory of the perfect picture asserted that the objects represented would be seen 'through the frame of the picture as if through a window' and, if this was true, it was implied that the pictured scene would be indistinguishable from the real scene. This analogy with a window opening on another world, a magic window, inspired painters for centuries and we owe a great debt to Gombrich [13] for reminding us of it. But, like most analogies, it can be misleading. The margins of a picture, the frame, could never be [32] mistaken for the occluding edges of a window, since the use of two eyes or the slightest movement of the head would betray the difference. That is, the existence of a world outside the window and extending behind the edges of the window, as contrasted with the non-existence of such a world, is specified by the kind of optical information called accretion-deletion of elements [29]. And so, despite all the stories of paintings that are said to deceive observers into trying to lift the curtain, or eat the grapes, or walk into the scene [30], I am sceptical. There would be *information* for seeing these things, of course, but there would also necessarily be for seeing a *painted* curtain, *painted* grapes and a *painted* scene. The notion of an image that is literally and actually indistinguishable from the reality is a myth. Pygmalion's cold statue was not a girl and the image that Narcissus saw in the pool was insubstantial, as he could have discovered at any time. The fallacy encouraged by an uncritical acceptance of the 'illusion of reality' is the belief that the perception of something pictured can *pass over into* the perception of it. A mediated perception cannot become a direct perception by stages. No matter how faithful, how lifelike, how realistic a picture becomes, it does not become the object pictured. Perception at second hand will never be perception at first hand.

A related fallacy is the belief that a picture is *similar* to the object pictured (which is false to begin with) and the notion that when similarity reaches a maximum it becomes identity.

WHAT ABOUT PICTURES OF NON-EXISTENT OBJECTS?

The new definition of a picture does not suggest, as did my old definition, that there must exist in the world, or have existed, an original scene for which it is an imitation, a substitute, a surrogate or a literal representation. There are pictures of mermaids, of angels, of buildings not yet constructed and of events that will never happen. The information provided by a picture is information for perceiving, in the widest sense of the term, not only for remembering something in the past but also for conceiving something in the future, in short for apprehending. The invariants of pictorial information are timeless. The experience obtained by a picture is *as if* one were confronted with a material layout of light-reflecting surfaces but *only* as if.

WHAT ABOUT AMBIGUOUS DRAWINGS AND REVERSIBLE FIGURES?

Displays which are ambiguous or reversible with respect to what is seen have been interpreted as proving that perceiving depends more on the perceiver than it does on the external stimulus. In the illusion of reversible figure-ground and that of reversible perspective, it is as if there were two different things in the same place.

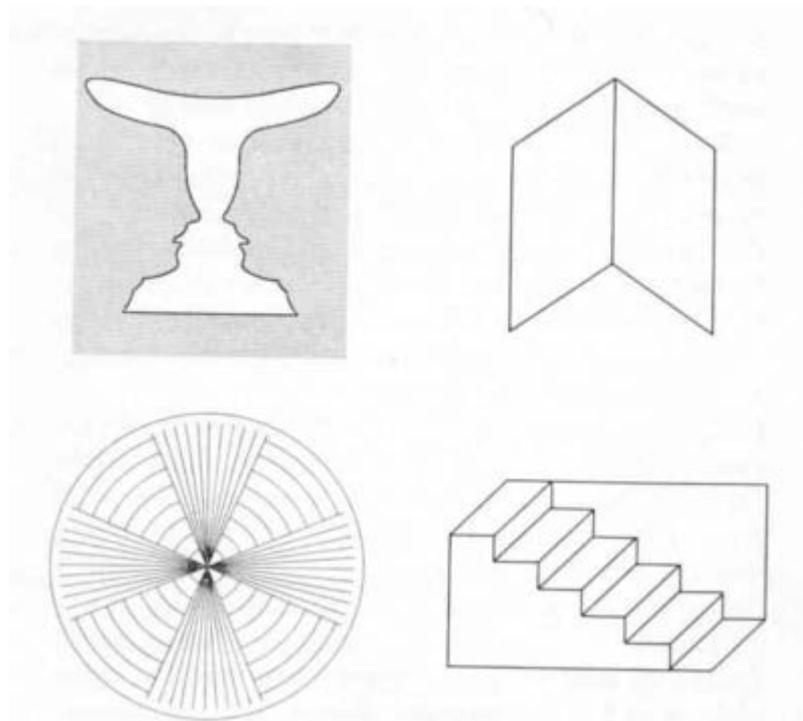


Fig. 3. Reversible surface-or-air and reversible convexity-or-concavity. On the left are two examples of ambiguous figure and ground (the goblet-faces display and the alternate Maltese crosses). On the right are two examples of reversible 'perspective' (the ambiguous book and the ambiguous staircase). Stare at the center of each drawing for a time; observe what happens.

The fact of two alternative percepts from the same drawing is very puzzling. The light to the eye has not changed when a pair of faces is seen instead of a goblet but the percept has (cf. Fig. 3). If such drawings are analysed as sources of information instead of mere stimulation, however, the puzzle becomes intelligible. The information in the array is equivocal [31]. There are two incompatible kinds of pictorial information in the light to the eye and the percept changes when the beholder shifts from one kind to the other. The information for depth at an edge, for what

hides what, has been carefully arranged to specify two different and opposite directions of depth. Equivocal representation in drawings of the edges and corners of surfaces in the world has recently been studied and is reported by Kennedy [12].

DISCUSSION

Two theories of pictorial perception have been described. Either we can see what is depicted in the same way we can see it when it is not depicted but confronts us or we can *understand* what is depicted in the same way we can understand it when it is described verbally. No other alternative has been considered in the debate. Neither theory is correct. It is true that perceiving what is represented is more like *seeing* it than like *understanding* it by reading or hearing about it. But it is not true that perceiving what is represented can ever be exactly like perceiving it in the world. Conversely, pictorial perception has more immediacy than the understanding of words. But all visual perception, indirect or direct, is based on [33] the pickup of information, not on the having of sensations; it is based on the information in an optic array not on the rays of radiant energy.

To speak of the information in an optic array does not imply that it consists of conventional symbols or that pictures constitute a language, for some of the basic principles of optics still underlie the reformulated discipline that I call *ecological* optics [32]. Herein lies an alternative to both the analogy with classical optics and the analogy with language. The structure of a picture is allied to the structure of perspective geometry, not to the structure of language. Both pictures and language *have* structure, to be sure, and in this limited sense it is possible to say that both have a sort of *grammar*. But the informative structure of ambient light is richer and more inexhaustible than the informative structure of language. Animals and men could see things long before men began to describe them and we can still see many things that we cannot, as yet, describe.

It is surely true that picturing is a means of communication and a way of storing, accumulating and transmitting knowledge to successive generations of men. So is speaking-hearing a means of communication and writing-reading a way of accumulating and transmitting knowledge. But the difference is that picturing exploits some of the information in the structure of the light, the space-filling light that is everywhere available as long as a clear medium of water or air has existed on his planet. And this is what visual perceiving does.

Not only do we perceive in terms of visual information, we also can *think* in those terms [33]. Making and looking at pictures helps us to fix these terms. We also can think in terms of verbal information, as is obvious, and words enable us to fix, classify and consolidate our ideas. But the difference is that visual thinking is freer and less stereotyped than verbal thinking; there is no vocabulary of picturing as there is of saying. As every artist knows, there are thoughts that can be visualized without being verbalized.

It is possible to suggest a new theory of pictorial perception only because a new theory of visual perception has been formulated. The latter is based on the radical assumption that light can convey information about the world and, hence, that the phenomenal world does not have to be constructed by the mind (or the brain) out of meaningless data. This assumption, in turn, depends on a new conception of light in terms of the array at a point of observation-light considered not merely as a stimulus but also as a structure. These ways of thinking about perception and light are unfamiliar but they clarify murky puzzles of long standing and they make the art of depicting very much more intelligible than it has been. It is now possible to distinguish between the pictorially *mediated* perception of the features of a world and the *direct* perception of the features of the

surroundings, and yet to understand that there is common information for the features they have in common.

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30. Cf. reference 13, p.206.
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34. A useful book has just been published that clarifies the little-understood phenomenon of perspective distortion in pictures. It is *Optics, Painting and Photography* by M. H. Pirenne (Cambridge: Cambridge University Press, 1970). Professor Pirenne has misgivings, like me, about the theory that perspective is a symbolic convention. He defends, as I once did, the point-projection theory of pictorial information, although cautiously. But he accepts the eye-camera analogy, as I do, and thus the new theory here proposed will seem very strange to him.

L'information contenue dans les images

Résumé - L'auteur passe en revue deux théories courantes et opposées sur la nature de l'image: (1) l'image est formée d'un faisceau de rayons lumineux convergeant vers un point précis le spectateur; chaque rayon correspond à une tache de couleur sur la surface de l'image et par conséquent celle-

ci peut être considérée comme un objet réel ou une scène dans la mesure où les rayons provenant de l'image sont semblables aux rayons provenant de l'objet réel; (2) l'image est formée par un ensemble de symboles qui sont à peu près comme les mots et le spectateur doit apprendre à la 'lire'. Selon la première théorie, un enfant peut percevoir un objet dans une image dès qu'il peut percevoir l'objet réel; selon la seconde, l'enfant doit apprendre à 'lire' l'image de la même façon qu'il doit apprendre à lire le discours écrit.

Il met en évidence ce qu'il y a de faux dans ces deux théories, montre qu'elles ne peuvent se combiner et suggère une nouvelle théorie basée sur l'hypothèse hardie que la lumière peut véhiculer de l'information et que par conséquent l'esprit (ou le cerveau) n'a pas besoin de construire le monde des apparences à partir de données dépourvues de signification. Cette théorie rend possible la distinction entre la perception du monde *médiatisée* par l'image et la perception *directe* de ce qui nous entoure tout en nous permettant de comprendre qu'une information semblable rende compte de leurs particularités communes.

Cette théorie précise la différence entre la pensée verbale et la pensée en images. La pensée en images est plus libre et moins stéréotypée que la pensée verbale; il n'y a pas de vocabulaire de l'image comme il y a un vocabulaire de la parole. Les artistes savent bien qu'il y a des pensées qu'on peut imaginer sans les formuler. [35]

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