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Real space and represented space: Cross-cultural perspectives

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Abstract: This paper examines the contribution of cross-cultural studies to our understanding of the perception and representation of space. A cross-cultural survey of the basic difficulties in understanding pictures – ranging from the failure to recognise a picture as a representation to the inability to recognise the object represented in the picture – indicates that similar difficulties occur in pictorial and nonpictorial cultures. The experimental work on pictorial space derives from two distinct traditions: the study of picture perception in "remote" populations and the study of the perceptual illusions. A comparison of the findings on pictorial space perception with those on real space perception and perceptual constancy suggests that cross-cultural differences in the perception of both real and representational space involve two different types of skills: those related exclusively to either real space or representational space, and those related to both. Different cultural groups use different skills to perform the same perceptual tasks.

Keywords: constancy; cultural differences; depth perception; field-dependence; form perception; illusions; perspective; picture perception; representation; space perception; vision

1. Introduction

This paper will examine cross-cultural studies of the perception of real space and representational space and their implications for psychological theory. It provides a conceptual framework based on a sample of studies judged to be of especial interest.

There are many reasons for doing cross-cultural studies, ranging from pure curiosity to systematic hypothesis testing. The approach here is the following: Different cultural groups are sources of information about essentially the same phenomena, certain phenomena being more readily observable in some groups than in others. A psychologist attempting to understand the phenomena exploits these fortuitous differences in the same way he exploits the high breeding rate and relatively large chromosomes of the fruit fly in genetic studies or (closer to our theme) the simple organization of the visual system of octopods in studies of vision.

We will examine the evidence stimulated by the two dominant cross-cultural approaches to studying real and represented spaces: Segall, Campbell, and Herskovits's (1963; 1966) worldwide investigations and Hudson's (1960; 1967) South African work. An attempt will be made throughout this target article, but especially in the concluding sections, to evaluate the implications of these studies.

2. Real and represented space

The title of this paper might be understood as suggesting that there are two distinct and incommensurate kinds of space, the pictorial and the real. Such an interpretation would be wrong, because although one can treat the two as independent and conduct investigations confined entirely to one of them, pictorial space is, despite claims by those philosophers who consider all representations to be based on conventions (Goodman 1969), not a convention but a derivative of real space. The same visual cues – most notably the Gibsonian (see Gibson 1971; 1978; 1979) density gradients – which give rise to the perception of distance in real space can be used to create illusions in pictures. Such an illusion can be evoked even by very simple pictures. Thus, when the diagram shown in Figure 1 is placed about 50 cm to the left of the reader, the trapezoid on the *right* is perceived as the larger of the two, but when the diagram is placed at about the same distance to the right it is the *left* trapezoid that appears larger. This change of size is, as Jerison (1967) observed, similar to the experience one has in real space when walking past two parallel rectangular walls that are at a right angle to one's path. One of the walls appears to expand and the other to shrink.

This intimate perceptual relationship between real and represented space is tacitly acknowledged in psychology by the frequent use of represented space to assess the perception of real space and vice versa. Practically all so-called spatial tests rely on pictorial input. (Hence there is inevitably a confounding of pictorial and spatial effects when they are used, and it is impossible to determine to what extent test scores are a consequence of differential familiarity with pictorial materials or of differences in spatial ability – a confounding, as we shall see, that is especially vexing when cross-cultural comparisons are involved.)

Hence two distinct but related kinds of measures of

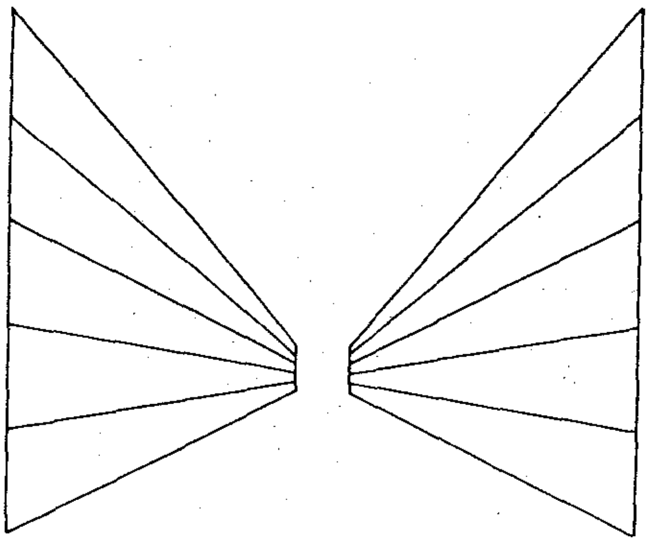


Figure 1. The relative size of the two "wings" of this figure changes as it is moved from left to right; the wing nearer to the observer always appears to be larger.

spatial perception are possible: those confined to a single space, be it real or pictorial, and those that define one space in terms of the other. The conventional measures of shape and size constancy belong to the first category, as do tests in which subjects answer questions about relations between aspects of represented space (for example, "is *X* in front of *Y* or behind *Y*?" or "is *X* closer to *Y* or to *Z*?") or transform representations of objects mentally to determine what a given object would look like if it were rotated or represented from another viewpoint, or what its surface would look like unfolded (see Eliot & Smith 1983). Measures involving models constructed in response to pictures (e.g., Dziurawiec & Deregowski 1986) and pictures drawn in response to models (e.g., Deregowski 1976b) belong to the second category of spatial perception test.

Real and pictorial space have unfortunately tended to be treated separately in cross-cultural studies, although there is evidence that investigating them jointly reveals more about their relationship and the relevant perceptual processes. Such evidence can be found in the "Western" findings of Goldstein (1979), whose American subjects viewed pictures at different angles and indicated by setting a pointer how they perceived the orientations of the represented objects and of the imaginary lines connecting them. There were considerable differences in the rates at which perceived orientations of various objects changed with the change of angle of view (Figure 2); and, more important, in spite of marked changes in orientation there were no corresponding changes in the perceived layout in the represented space. Discrepancies between judgements of orientation and of layout suggest that the picture's surface defines two types of pictorial space: one inside and one outside the picture. Spatial layout, Goldstein maintains, is perceived in terms of the former and rotation in terms of the latter. Thus, the effect of the perceiver's angle of view on pictorial space was clearly different from what its effect would have been on real space, in which such inconsistent changes do not occur, as shown by Deregowski and Parker (1988) in their study of the perception of pictorial space in Van Eyck's *The Music Room* and the perception of models in real space based on that picture.

Opolot (1976) and, earlier, Page (1970) have done cross-cultural studies on the relation between real space and represented space. In Opolot's study, four pictures from Hudson's test (Figure 17) were used. Observers were asked to judge (1) the distance between the represented figures and themselves and (2) the distance between the represented figures (the latter being the standard procedure). When they were asked about the distance from themselves their responses were more affected by the represented space than under the standard procedure, that is, in terms of Hudson's test (see sect. 7, para. 2) they made "3D" responses more often. The former kind of question seems to have brought the observers into the represented space and the latter kind seems to have kept them, perceptually, outside that space, separated from it by the barrier of the picture's surface. Goldstein's work, as well as Opolot's, suggests that an exploration of the relation between the two kinds of space may be desirable; cultural differences in picture perception, to be reviewed below, further suggest that such studies should be carried out cross-culturally.

3. Two kinds of images

Two-dimensional images may be seen as representing three-dimensional objects for two distinct reasons. They may either contain cues that lead indirectly to the recognition of a three-dimensional object without evoking the illusion of space (such as the elephant and manikin shown in Figure 3) or they may evoke the illusion of space directly (such as the truncated pyramid in Figure 4). In the first case, the perception of the spatial attributes of the object is modified by the recognition of the object; in the second it is not. The former kinds of image will be referred to as 2D images *without* direct three-dimensional cues (2/3i) and the latter as 2D images *with* direct 3D cues (2/3d). 2/3i pictures differ radically from 2/3d pictures, which have a readily perceptible 3D quality (although they do not necessarily represent any known object). Nor does direct perception of three-dimensionality imply that the object as seen could actually exist; indeed, the object may be seen as 3D and simultaneously as impossible. This happens with the "two-pronged trident" (Figure 5), Reutersvard's triangle (Figure 6), and other figures representing "impossible" objects (for a collection of such pictures see Ernst 1986). In some instances, the strength of the illusion is such that the impossibility of the represented object is not noticed and any suggestion that it is impossible is dismissed by the observer as nonsense. Thus, many Western observers wrongly maintain that Figure 4 shows a truncated pyramid on a triangular base, although the figure cannot be a representation of such a pyramid (see Kulpa 1983; 1987).

The perceptual system's attempts "to make sense" of the stimuli by creating 3D objects – which is after all one of the system's raisons d'être in our three-dimensional world – are perhaps less surprising than its attempts to create 2D objects. This effect is all the more surprising because the recognition of the representation and the simultaneous perception that it is flat imply a

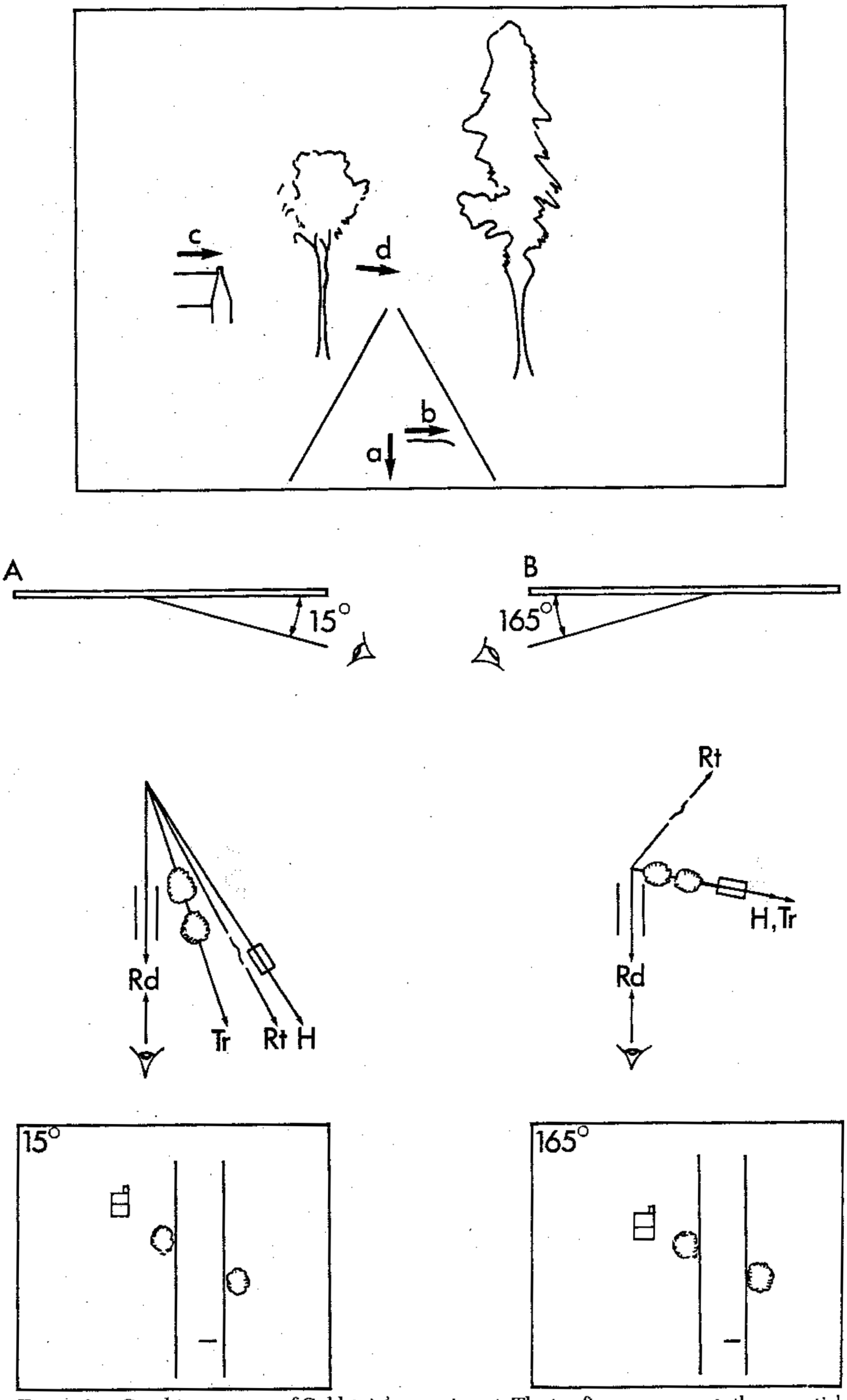
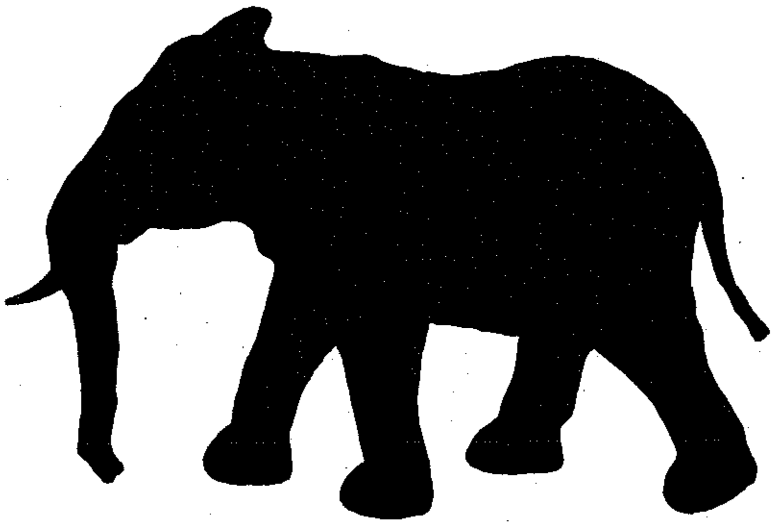


Figure 2. Graphic summary of Goldstein's experiment. The top figure represents the essential elements of the picture used: a house (H), a road (Rd), a rut in the road (Rt), and two trees (Tr). The diagrams underneath (A & B) represent two of the angles at which the picture was viewed and the figures below them represent the responses obtained under these conditions. The top picture of each pair shows the perceived direction of the various elements (a, b & c) and of the line connecting the two trees (d). The bottom picture shows the arrangement of the elements within the stimulus picture as reproduced by the subject. It is apparent that the task of judging represented angles that involves extrapolation from the represented space into real space is markedly more affected by the angle of view than is the task of reproducing the arrangements contained wholly within the pictorial space.



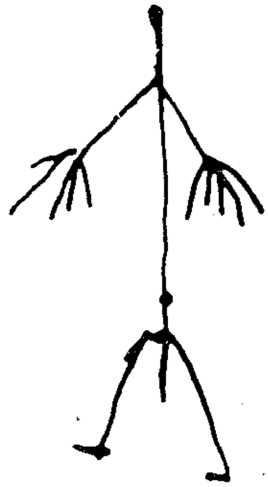


Figure 3. Examples of 2/3i figures in which the three-dimensionality is conveyed *indirectly* through knowledge of the represented objects: (a) a silhouette of an elephant and (b) a drawing done by a Tallensi. Neither of these figures conveys directly that the represented objects are 3D.

reconciliation of two contradictory elements: the three-dimensionality of the object and the flatness of the representation. Yet ambiguous patterns such as the one shown in Figure 7 – which is derived from a Palaeolithic engraving and is recognized as a human face or as two faces in confrontation – are readily perceived and have provided substance for much discussion by Gestalt psychologists (Petermann 1932; Rubin 1915).

Even flat figures, however, though individually seen as having no pictorial depth, can in combination create three-dimensional pictorial space. Two similar figures of different size placed at different heights within the plane of the picture evoke the perception of depth in many viewers, the more elevated figure being seen as more distant. It is parsimonious to assume that this percept should be attributed to the same perceptual mechanism as that responsible for interpreting density gradients as cues to the shape and orientation of surfaces in space and the one responsible for perception of the Ponzo illusion (Figure 8) and its derivatives.

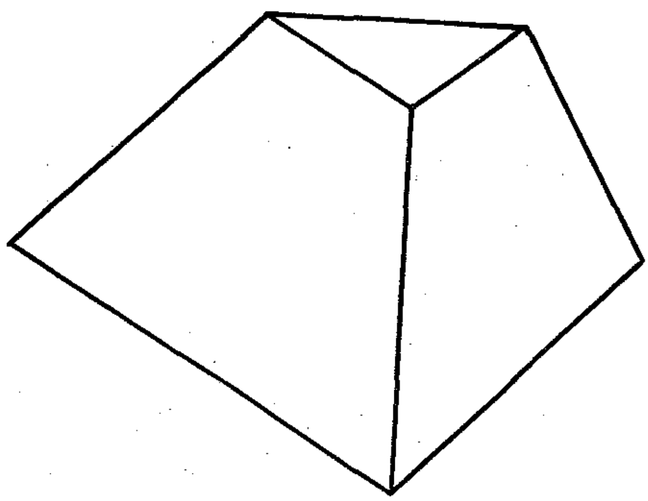


Figure 4. An example of a 2/3d figure of a solid that conveys the three-dimensionality of the represented object *directly*. The figure is *seen* as 3D although it does not represent any readily nameable object. It is "impossible" if it is taken (as it generally is) to be a truncated pyramid on a triangular base. (Since a point can only be projected as a point, extensions of the three sloping edges of a representation of the truncated pyramid would converge at a point. This does not happen here; the extended edges converge in pairs.)

The distinction between 2/3i and 2/3d pictures partitions a category that Gibson (1978; 1979) thought was homogeneous. He postulated that all pictures, including those of stick figures, are displays of invariants that are nameless and formless and are derived from the observation of representations of objects. According to Gibson, a picture is a surface that furnishes an optical array of "formless invariants" to an observer. Its representational techniques have arisen from the fortuitous discovery that certain scribbles yield invariants that coincide with invariants derived from real objects. This does not seem to be the full story, however. The evidence Gibson cites is, as we will see, flawed. He maintains that drawings have been found in all cultures since the time of Cro-Magnon man. One would indeed expect this if his theory of the origin of pictures were correct. Fortes (1940; 1981), however, describes a population long after Cro-Magnon times that neither had nor knew pictorial art. Fortes asked such subjects (the Tallensi of the Gold Coast, now Ghana) to draw. They did initially scribble on paper (Figure 9), but when asked to draw something in the environment, they abandoned their scribbles and set about the task purposefully, making 2/3i, sticklike drawings (Figure 10). There was no suggestion in their behavior of stumbling accidentally upon such drawings and of experiencing a chance discovery of invariants similar to those obtainable from objects in their environment. Their act of drawing was intentional and their first figures were deliberate reflections of their intentions.

These subjects did not, however, regard their primarily 2/3i stick figures as duplicates of the objects represented. That agrees well with Gibson's view that a picture does not create an illusion of reality; it contradicts Gombrich's (1962) view that it may do so. However, one

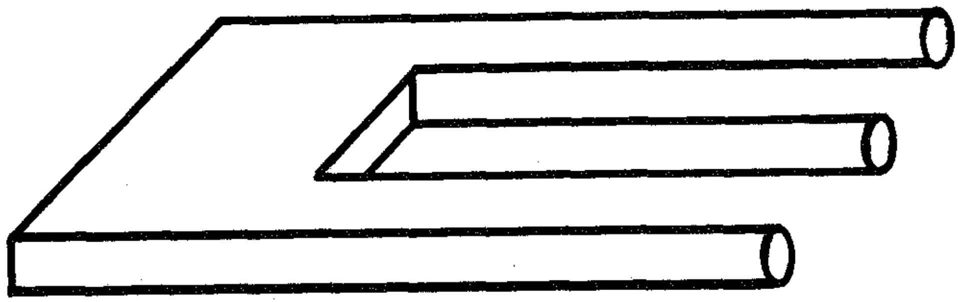


Figure 5. The two-pronged trident, an "impossible" figure.

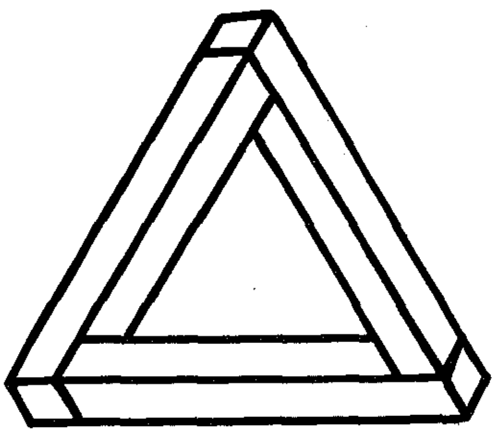


Figure 6. A Reutersvard's triangle, an "impossible" figure.

would not expect a 2/3i picture to create an illusion; and ample evidence is examined by Gombrich (1979) and Topper (1979) in their discussion of Gibson's theory of pictorial perception, showing that pictures can be mistaken for represented objects. Further and very cogent evidence for the ability of pictures to evoke an illusion of reality is provided by animal studies: When a primate tries to pick up a picture of a spider (Heusser 1968) it is surely responding to an illusion. Thus, both cross-cultural and animal studies combine to expose a weakness in the extension of Gibson's ecological approach to picture perception in general. Such an approach is probably more applicable to 2/3d than to 2/3i pictures.

The implications of these findings are strengthened by the errors made by subjects with limited experience with pictures when they are presented with pictures. Clearly, where no recognition of the represented objects occurs, the putative invariants must be too weak to evoke a percept, and on the occasions when misidentification occurs the invariants must be less stable than their name would imply; indeed, they may even be subject to interpretation as perceptual hypotheses in the manner described by Gregory (1970).

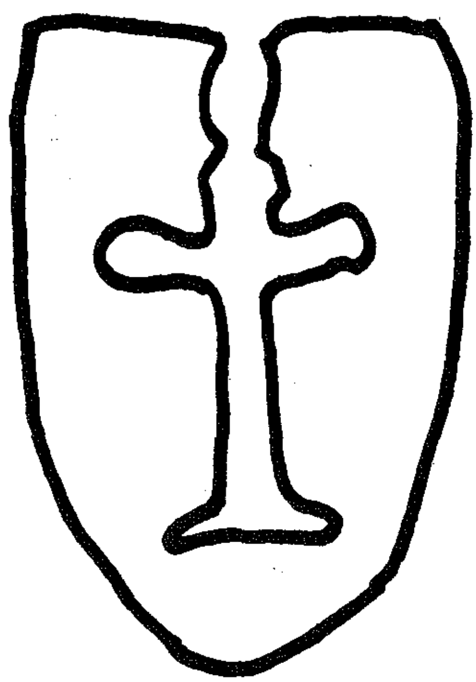


Figure 7. An ambiguous 2/3i figure derived from a Palaeolithic engraving.

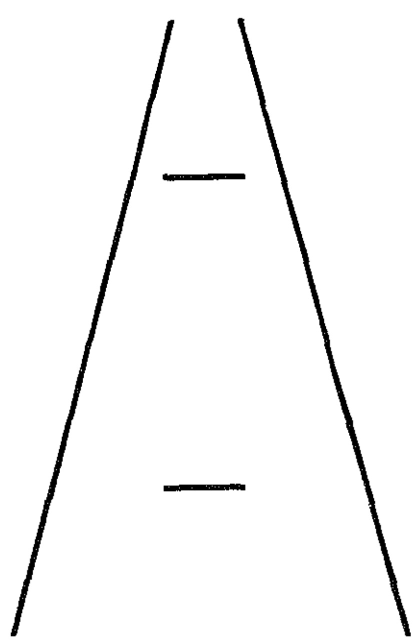


Figure 8. The Ponzo illusion. The upper of the two equal and parallel lines is generally seen as longer.

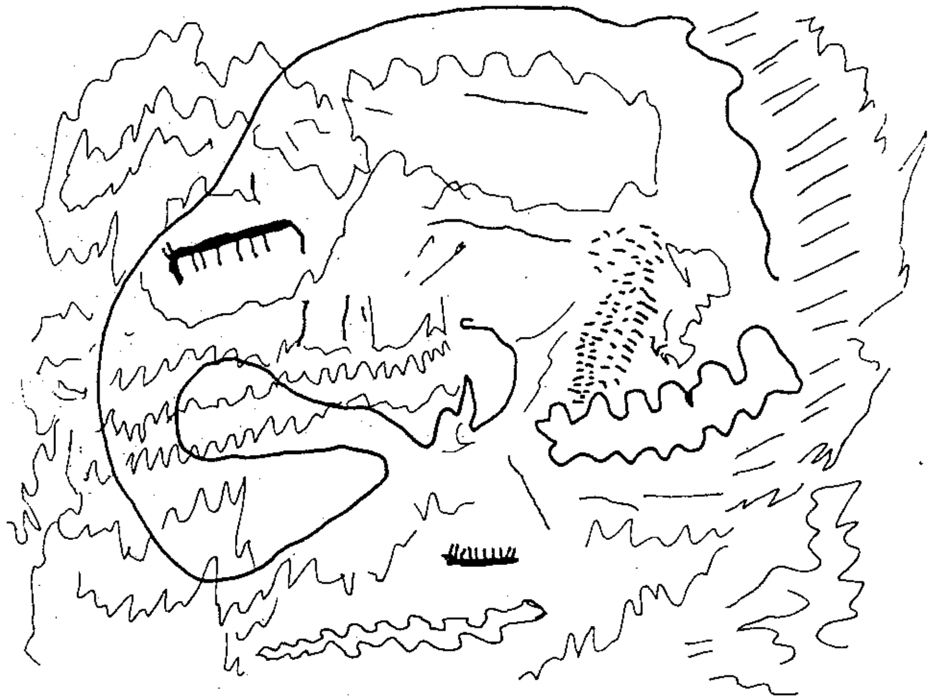


Figure 9. Scribbles made by a Tallensi when first attempting to draw.

The distinction between 2/3d and 2/3i representations and its implications for the Gibsonian approach was acknowledged, perhaps unknowingly, by Hagen (1974). She confined her discussion of the Gibsonian model to pictures she described as Western and post-Renaissance in style, that is those in which 2/3d elements predominate.[1] These observations suggest that in studying the perception of pictorial space, both 2/3d and 2/3i elements ought to be examined (see also Conley 1985). That will accordingly be done here.

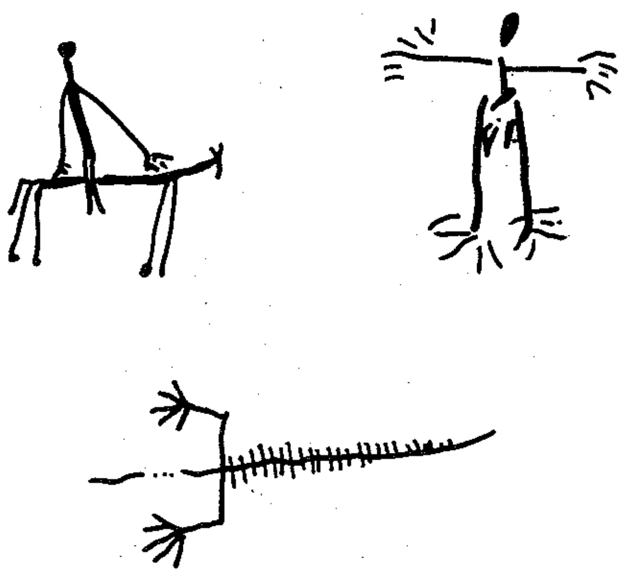


Figure 10. Drawings of a horse and rider, a woman, and a crocodile made by Tallensi. (A Tale drawing of a man is shown in Figure 3.)

4. A bit of history

The hypotheses which lie at the foundations of studies of picture perception (Hudson 1960; 1967) and of studies of visual illusions (Segall et al. 1963; 1966) have on several occasions been anticipated by various travellers in (then) exotic lands, most notably by members of that staunch and ingenious body of men – the Scottish missionaries. Their primacy should not pass unrecorded. Thus, for example, Dr. Laws (see Deregowski 1983) anticipated both the effects of environmental experience on perception and the difficulties in perceiving pictures, as shown by the following quotations, the first of which pertains to the difficulties encountered in training girls for domestic service:

> At her home the house is round, the baskets are all round, a straight line and a right angle are things unknown to her or her parents before her. Day after day, therefore, she will lay the cloth with the folds anything but parallel with the edge of the table. Plates, knives and forks are set down in a corresponding manner, and it is only after lessons are repeated, and much annoyance, that she begins to see how things ought to be done and tries to do them. (Laws 1986)

That can be juxtaposed with: "In a carpentered western world such a great proportion of artifacts are rectangular that the habit of interpreting obtuse and acute angles as rectangular surfaces extended in space is a very helpful one. . . . In a culture where rectangles did not dominate, this habit might be absent" (Herskovits et al. 1956, p. 9). Dr. Laws's observation can also be juxtaposed with reports of considerable orientational errors made by African subjects required to reproduce geometrical figures, both by drawing and by constructing a model (Biesheuvel 1952a; 1952b; Jahoda 1956; McFie 1961; Nissen et al. 1935; Shapiro 1960).

The second observation by Dr. Laws describes the difficulties in the perception of pictures:

Take a picture in black and white, and the natives cannot see it. You may tell the natives: "This is a picture of an ox and a dog," and the people will look at it and look at you and that look says that they consider you a liar. Perhaps you say again, "Yes, this is a picture of an ox and a dog." Well, perhaps they will tell you what they think this time. If there are boys about, you say: "This is really a picture of an ox and a dog. Look at the horn of the ox, and there is his tail!" And the boy will say, "Oh! yes and there is the dog's nose and eyes and ears!" Then the old people will look again and clap their hands and say, "Oh! yes, it is a dog!" When a man has seen a picture for the first time, his book education has begun! (Laws, in Beach 1901)

That can in turn be juxtaposed with the description of the responses of a Me'en (Mekan) of Ethiopia to a large picture painted on coarse cloth. The viewer is a man, about 35 years old. He is looking at a large figure of a dik-dik (a small antelope).

Experimenter: (points to the cloth) "What do you see?"
The Me'en: "I am looking closely. That is a tail. This is a foot."
Experimenter: "What is the whole thing?"
Me'en: "Wait. Slowly, I am still looking. In my country this is a water-buck."

The slow and laborious process described bears a striking similarity to that described by Dr. Laws. It is also reported that, just as in Laws's case, some of the Me'en failed to identify the represented objects (Deregowski et al. 1972).

5. The absence of picture perception

Perhaps the most striking reports of perceptual difficulties concerning pictures are those describing how "non-Western" observers failed to recognize pictures as being pictures, although they seemed perfectly clear to "Western" observers (Barley 1986; Doob 1961; Laws 1886). The failure is particularly surprising when one reflects that Rorschach blots are readily perceived as representations of objects. The effect is also rather poorly documented and, in some of the reported cases, may well involve factors other than those immediately associated with pictorial perception. Thus it is possible that observers sometimes failed to see a picture as a representation because they were paying attention to something else. That was so with some of the Me'en tested by the Muldrows (Deregowski et al. 1972). When they were given pictures printed on paper they attended to the paper – a strange material to them – and not to the surface pattern. They felt the paper, sniffed it, crumpled it, and listened to the crackling noise it made; they nipped off little bits and chewed them to taste it. When the same population was presented with figures printed on coarse cloth, a material with which they were familiar, this elaborate scrutiny no longer took place and the observers did attempt, albeit not always successfully, to make sense of the surface pattern. This dominant influence of the material on which pictures are presented is similar to a much earlier finding among the Yoruba (Nadel 1939/1946), a pictorially sophisticated population who used outline representations of common objects (for example, a man, a hut, a crocodile) as decorative motifs for their leatherwork and their carvings. They could identify such representations readily but not when the same outlines were presented on paper, that is, in a context that was culturally alien to them.

No other experimental reports on populations as isolated as the Me'en are available, and the earlier reports, from the time when pictureless cultures were thriving, are so inconsistent that one wonders whether some of the complete failures to recognize a picture may have been due to misdirection of the observers' attention, either because of the sheer novelty of the material (as in the case of the Me'en above) or because of a misunderstanding of the instructions. Imagine the following scene: A traveller: "Would you like to see your son?" A native: "Yes." The traveller: "Here you are. . ." And the photograph is handed over. Such a hypothetical offer is clearly open to a misunderstanding, with the observer, as sometimes reported, turning the photograph over and over. Lest this hypothetical scene appear too fanciful, consider this description by Barley (1986) of Dowayo responses to maps: the Dowayo of North Cameroon were amazed at Barley's ability to determine the locations of various villages by means of a map. This amazement led to even greater puzzlement when they found that Barley could not answer questions about the inhabitants ("Who is the headman?") of the villages he was able to locate.

Some of the failures to perceive pictures are similar to those observed in certain mental illnesses. Schizophrenics sometimes fail to recognize their bodies in photographs (Arnhoff & Damianopoulos 1964). Luria (1973) provides a graphic description of how a patient suffering from visual agnosia responds to a pair of spectacles; those responses parallel closely the responses of the Me'en. Furthermore, the responses of schizophrenics to such diagnostic tests as the Rorschach and the Thematic Apperception Test are often similar to the responses of the pictorially unsophisticated to pictures. It would not be justified, however, to suggest similarity of causes. Shapiro's (1960) study supports this caveat. He tested a group of menial workers from Malawi using Kohs's patterns (Figure 11), which they were asked to copy. Many of

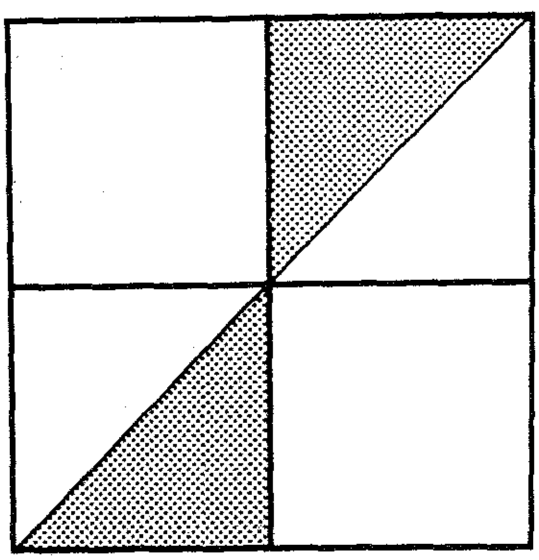


Figure 11. An example of a Kohs pattern. In the actual stimulus the shaded areas are red.

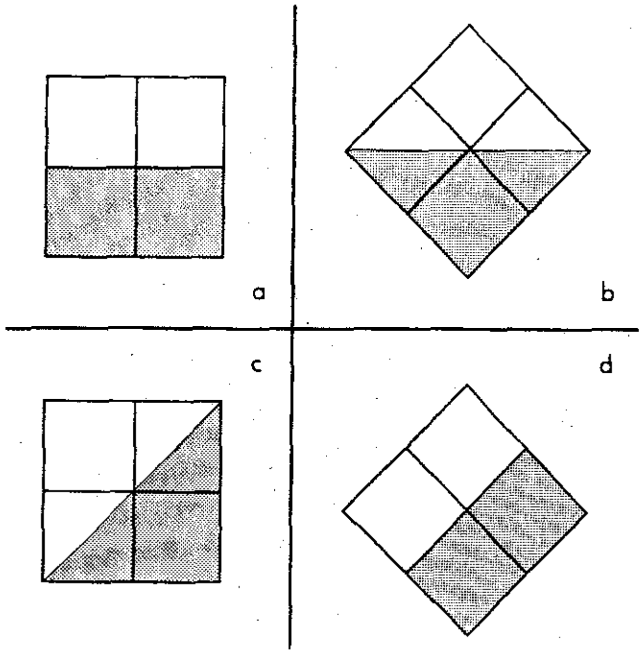


Figure 12. Four Kohs-type patterns illustrating the concepts of symmetry and stability. The figures in the top row are said to be symmetrical, those in the first column are said to be stable. Figure (d) is both asymmetrical and unstable.

the drawings showed the patterns, but in incorrect orientations. Some of these errors were as large as those of brain-damaged patients in Shapiro's London hospital. His sample of African subjects did not have other symptoms associated with brain damage. Shapiro speculated that the effect may be that of illiteracy or of low intelligence, perhaps in interaction with "being African." Further studies of this phenomenon (Deregowski 1974a; 1977; Jahoda 1976; 1978) show that African subjects similar to those studied by Shapiro have a systematic tendency to construct figures that are seen by subjects as more symmetrical and perceptually stable than the stimulus figures (examples of relevant figures are shown in Figure 12); this confirms Shapiro's observation that the African difficulties had a different origin from those of his patients. The observed similarity in the responses here is probably not a fruitful source of hypotheses.

There are also reports showing that reducing the influence of the nonpictorial cues greatly enhances perception by the pictorially unsophisticated, sometimes with rather dramatic consequences, as in the case of a slide show in Uganda reported by Lloyd (1904) early in the present century. The event was described thus:

> When all the people were quietly seated, the first picture flashed on the sheet was that of an elephant. The wildest excitement immediately prevailed, many of the people jumping up and shouting, fearing the beast must be alive, while those nearest to the sheet sprang up and fled. The chief himself crept stealthily forward and peeped behind the sheet to see if the animal had a body, and when he discovered that the animal's body was only the thickness of the sheet, a great roar broke the stillness of the night.

It will also be recalled that Livingstone had great faith in the efficacy of his magic lantern (Livingstone 1857), and that there is evidence that some pictorially unsophisticated populations perceived pictures easily. Thomson (1885), for example, reports (p. 454) that "A few photographs of some of their charming white sisters which I happened to have with me were a great source of delight" to Wataveta women.

There are, however, some contrary and puzzling and not easily dismissible findings, as in Landor's (1883) report of his life among the Ainu of northern Japan. His Ainu companions who saw him draw a picture could not say what it represented. More recent observations by such distinguished and experienced researchers as Doob (1961), Cole and Scribner (1974), and Barley (1986) show similar difficulties. The Fulani of Nigeria, among whom Doob worked, had on occasion labelled a distinct picture of an aeroplane a fish. Cole and his coworkers presented the Kpelle with very clear photographs (two are reproduced in Cole and Scribner's [1974] book) and some of these subjects misperceived them. Dowayos, to whom Barley (1986) showed postcards of animals for identification, could not identify them. The balance of the evidence is therefore that, although it occurs infrequently, clear pictures are misperceived, or, to be more precise, pictures that are perceived in some cultures are not perceived in others. The frequency of that is probably so low that the effect is of little consequence as far as the use of pictures for mass communication in illiterate societies is concerned, but the effect is nevertheless of great interest to students of perception. It is regrettable, therefore, that the phenomenon has not been investigated more thoroughly.

It should be noted that whereas failing to perceive a picture is symptomatic of defective picture perception, treating a picture as if it were an object is not open to equally unambiguous interpretation. Such a response may result from any combination of 2/3d and 2/3i cues – from a trompe l'oeil picture at one extreme and a purely 2/3i representation of a single feature of an object at the other – and the observer may or may not be aware that he is viewing a picture. The consequent complexities make it difficult to interpret apparently equivalent responses of men and animals to pictures. A lover kissing a photograph of her paramour cannot be said to be treating a picture in a manner equivalent to that of a primate trying to pick up a portrayed insect (Heusser 1968; Mariott 1976), because whereas we can be reasonably sure that the representation of a paramour is not taken for a paramour we cannot be sure that the monkey does not think that it sees a real insect (indeed one would be inclined to think it does). In fact, appropriate responses are often made to very minimal 2/3i cues by much simpler organisms than monkeys, as Hinton's (1973) analysis of natural deception shows. Birds, he points out, respond with fear to eye spots on wings of butterflies and moths. (Because these spots are on flat surfaces they can fairly be regarded as pictures.) Such a reaction to a picture is probably better interpreted as showing that birds react to partial cues as if the real object were present rather than that they *see* the spots *as* representations of a vertebrate's eyes. The work on monkeys' fear responses to pictures (e.g., Humphrey and Keeble 1974) should probably be interpreted in a similar manner.

The available evidence, unfortunately, fails to show how much primates rely on the recognition of specific 2/3i features and how fully they grasp the representation as a whole (for an extensive review of this topic see Cabe 1980). There is a relevant study by Davenport and Rogers (1971) in which one orangutan and two chimpanzees were required to match photographs to haptically explored objects such as tap-handles or padlocks. The animals were successful at the task. The result does not dispel the possibility that they saw the photographs of objects not as photographs but as proper objects; or that they saw only some (to them salient) features of objects in photographs, not seeing them as representations of whole objects.

Finally, it is also possible that the apes saw the pictures as purely 2/3i representations of geometric shapes and responded by matching these abstractions (such as "a thing with a hole" for the padlock, "a thing with prongs sticking out" for the tap) to the objects.

This caveat applies to similar studies involving young children. When a subject discriminates among pictures by showing greater interest in those that do not represent familiar objects (as DeLoache et al. 1979 showed with young children using dolls and pictures of dolls as stimuli), this is not clear-cut evidence of recognition but merely an effect of the similarity of the cues abstracted from the object and the representation. Verbal responses to pictures, which can only be obtained from older children, are more informative. They can indicate the identification of an object and are therefore comparable to the behavioural responses of primates that were just mentioned. The validity of such responses is increased by presenting pictures in a way that ensures the availability of nonrepresentational cues, such as the flatness of the surface, the frame and the immediate surround, as well as representational cues. It could be argued, however, that fully skilled observers cannot only ignore the nonrepresentational cues when these are irrelevant but can also use them when appropriate (Serpell & Deregowski 1980). A convincing experimental demonstration of picture perception by a primate would accordingly involve a measure of its ability to exploit such nonrepresentational cues. For example, one might test the ability to interpret a picture viewed at an angle, a task investigated by Hagen (1976), Goldstein (1979), and Deregowski and Parker (1988). The present author knows of no such investigations on nonhuman primates.

6. The nature of picture difficulties

Further puzzling observations are reported from remote parts of New Guinea by Forge (1970). His informants occasionally asked him to show them photographs of their deceased relatives that he had taken in the course of his anthropological investigations; they were extremely anxious to see the pictures and sometimes travelled considerable distances to do so. They were therefore bitterly disappointed when they were unable to see their relatives in the photographs, a failure attributed by Forge, for intuitive rather than empirical reasons, to the fact that the deceased were photographed at work rather than in the rigid poses prevalent in the photographs made locally (the only photographs with which his visitors were likely to be familiar). The failure, assuming that Forge's attribution is correct, cannot easily be explained by lack of clarity or some other characteristic of the photographs. It is more likely to result from a mismatch between the expectation and what is actually encountered, for which lack of expertise is responsible.

When, as in the cases described above, a person fails to see a picture as a representation, then the perception of the spatial properties of the object/scene cannot occur, and the case in question is therefore marginal to the focus of this article; it does, however, lie sufficiently near to its main thrust to merit the brief examinations just presented.

Cross-cultural observations such as that of Forge contrast with a single and deservedly much cited study of an American child who was brought up to the age of 19 months without explicit instructions about the representational nature of pictures and with only such accidental exposure to pictures as was unavoidable in his culture. He was nevertheless able to name representations of familiar objects correctly (Hochberg & Brooks 1962). This evidence could be thought to show that pictures are instantly and fully perceptible. That is not so. The ability to interpret pictures is achieved gradually (Elkind 1969) and there are, as Sigel (1978) has found, considerable intergroup differences. Even relatively sophisticated observers find some pictures difficult. Problems experienced by such observers when viewing a Street figure (Figure 13) and asked to build a cohesive image from seemingly unconnected elements suggest that similar difficulties are likely to be present, in some degree, in all cultures. Furthermore, there are reports that in some cultures these difficulties are particularly severe, the observers failing to construe coherent percepts from the pictorial elements presented to them.

Analogously, the difficulties some observers from pictorially sophisticated cultures experience when asked to disembed a figure from a mass of visual noise (Figures 14a

Figure 13. A Street figure all elements of which must be perceptually combined for correct recognition of the depicted object – a horse and rider.

and c) suggest that these difficulties are also likely to be encountered in other cultures (see, for example, Berry 1966).

Both kinds of difficulties (those of structuring from scattered elements and those of disembedding) may affect 2/3i and 2/3d figures, but neither the extent of their influence of the two types of figures nor its cross-cultural variation has been systematically investigated. There are several studies dealing with various isolated aspects of the problem, however.

The two kinds of difficulties that have just been described can be conceived as consequences of two orthogonal factors affecting the task (Deregowski 1980b). The first has been called *Type of Array.* It ranges from *anarchic,* in which elements of the display form separate but mutually unrelated entities (Figure 14c), to *totalitarian,* in which all the elements must be integrated to make the recognition of the pattern as a representation possible (Figure 14b). The second factor has been called *Figure/Background Separation.* It ranges from *difficult,* in which the figure has to be detected in a mass of irrelevant detail (Figure 14c), to *easy,* in which the figure and the background are clearly distinguishable (Figure 14d).

Combinations of the four distinctive values of these two factors are illustrated in the following figures, which have been used as experimental stimuli.

a. Totalitarian and highly embedded: Witkin's Embedded Figures Test stimuli (Figure 14a). (For this and related tests see Eliot & Smith 1983.).

b. Totalitarian and nonembedded: Figures of the type used in the Gestalt Figure Completion Test (Eliot & Smith 1983). These consist of several distinct, yet meaningless elements that in combination, and with some mental completion, form a recognizable image (Figure 14b).

c. Anarchic and highly embedded: Overlapping figures representing objects (Figure 14c). Such stimuli were used by Ghent (1956); see also Goldsmith (1984).

d. Anarchic and nonembedded: Scattered representations that cannot be combined to form a meaningful pattern (Figure 14d).

The four combinations in Figure 14 can appear in both 2/3d and 2/3i figures and can be used to describe the perceptual attributes of figures as they are perceived in different cultures (Deregowski 1980b).

Binet (1890) observed that young French children did not find drawings of "syncretic" animals (animals built of elements derived from different species, for example, an elephant's head on a cow's body with cat's legs and horse's tail) difficult to name. They simply named them after one of the parts of the animal and were satisfied with that. Similar observations were later made by others. Elkind (1969) constructed a set of ingenious figures consisting of unembedded elements that were each a clear representation of an object. One can combine these elements to form an entirely new percept. For example, various fruits can be combined to yield a face (Figure 15). When such figures were used in the United States, children tended to list individual elements rather than naming the com-

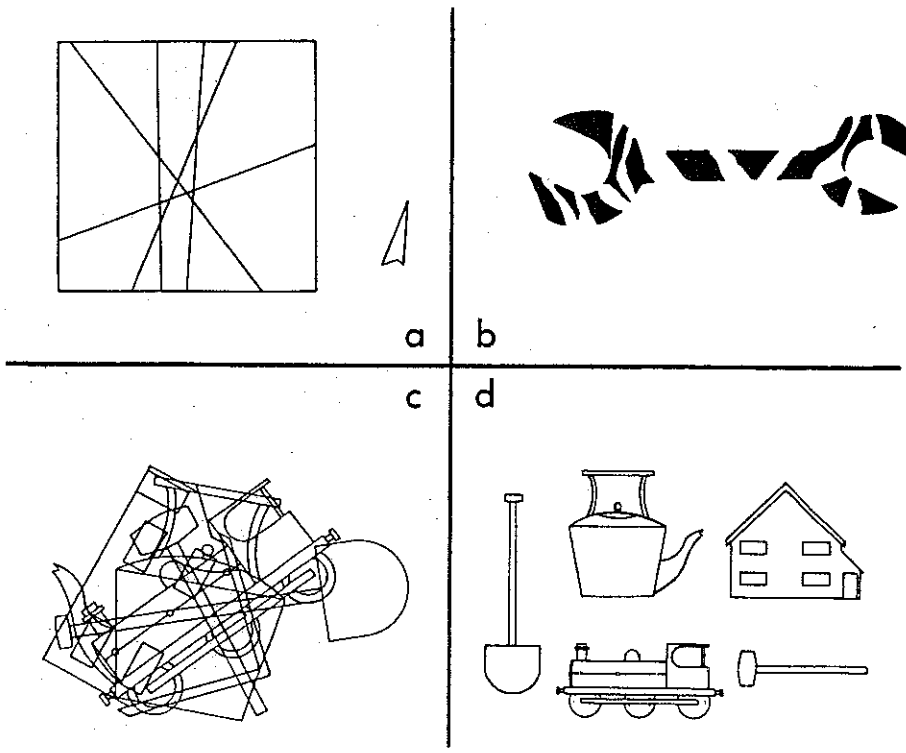


Figure 14. Figure illustrating the following terms: "embedded" (Figures a & c), in which the element sought (in the case of Figure a, it could be the concave quadrilateral shown) has to be disentangled from other elements; "unembedded" (Figures b & d), in which the elements are not obscured by other elements; "totalitarian" (Figures a & b), in which the elements form, when summed, meaningful arrays; and "anarchic" (Figures c & d), in which the elements are mutually independent.

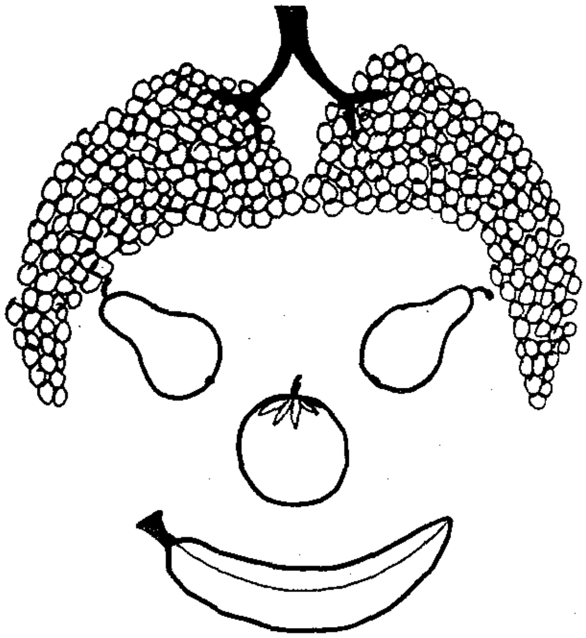


Figure 15. A figure composed of fruit. A certain amount of sophistication appears to be called for in order to see this fruit arrangement as a face.

posite figure. Ausburn and Ausburn's (1983) observations that were gathered among the Baruya (Papua New Guinea) suggest that such responses might have accounted for the low scores attained by adult subjects on the Matching Familiar Figures Test developed by Kagan (1966). In that test, a subject is presented with a picture and required to find an identical picture that is presented in an array of distractors. The subjects, it appears, found it difficult to attend to several details of the stimuli and tended to use only one detail for matching. Parsimony suggests that the same factor was responsible for the responses obtained by Shaw (1969) in rural Kenya: His tortoise representation (Figure 16) was described by some as a snake, by some as an elephant, and by some as a crocodile. The descriptions are explained by Shaw as deriving from various elements of the figure taken in isolation. Thus when the body of the figure is ignored and only the head and the neck are taken account of, these clearly look like a serpent; similarly, the feet alone look like an elephant, and the markings on the back of the shell of the tortoise are similar to those on the backs of Kenyan crocodiles.

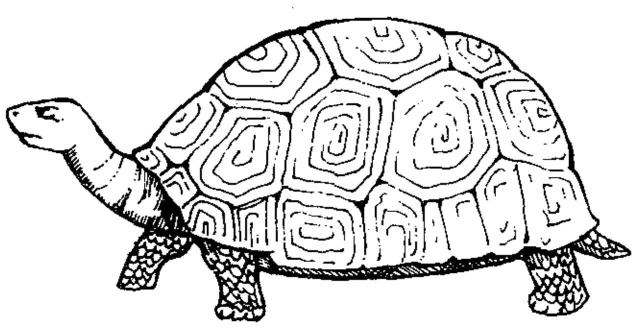


Figure 16. A tortoise that was described as an elephant, a snake, and a crocodile by some Kenyan observers (Shaw 1969).

Thus, although the figure was not perceived in accordance with the draughtsman's intention, it was nevertheless perceived as representing an object (and a different object in each of the three cases cited). The reports do not allow us to determine whether the spatial properties of these objects were perceived directly. In terms of the schema put forward earlier, some of Shaw's subjects saw the figure as less well integrated (i.e., more anarchic) than either he or the draughtsman thought it was, and probably more anarchic than it would appear to be to most observers.

There is evidence suggesting that lack of integration may affect 2/3d stimuli as well. This evidence derives from three experiments involving so-called impossible figures. In the first of these, Zambian schoolchildren were required to copy the two-pronged trident (Figure 5) displayed in a special box. They could open the box and look at the stimulus for as long as they wished, but they had to close the box and wait for a preset interval before beginning to draw. If they found the drawing impossible to complete, they were allowed to look again and thus to initiate another cycle of looking, waiting, and drawing. They could repeat the cycle as many times as they wished until they arrived at what they judged to be a correct drawing. The total time that subjects kept the box open and viewed the model was recorded. The same subjects were also required to build, using plasticine and bamboo sticks, simple geometric models shown in pictures (e.g., Figure 17; this *Construction Task* will be discussed later).

The subjects were classified as 2D or 3D *perceivers* depending on whether or not their models were flat or clearly spatial, that is, whether the subject perceived the stimulus figure as 2/3d. Those who perceived the pictures as 2/3d, and constructed 3D models, took relatively longer to copy the "two-pronged trident" figure than those who built flat models. This result was interpreted as showing that the 2D-model builders, unlike the 3D-model builders, did not perceive the spatial properties of the impossible figure; they were unaware of the contradictions inherent in the object represented in the figure and therefore merely copied a flat pattern, not a particularly difficult task (Deregowski 1969). However, a later study (Young & Deregowski 1981) suggests that such an explanation is oversimplified. Young demonstrated that English schoolboys do perceive various elements of such impossible figures as having spatial properties; they do not, however, integrate those elements as closely together as more sophisticated observers do. That is, the extent to which a stimulus is regarded as anarchic decreases with sophistication, and perceiving such stimuli as anarchic makes them easy to copy. The same procedure was used by Deregowski and Dziurawiec (1986) in testing African men of very limited formal education; concordant results were obtained. These various groups seemed to experience a difficulty similar to that expressed by Binet's (1890) subjects.

The above interpretation is supported indirectly by another body of data, namely, Segall et al.'s (1966) observations on the perception of illusions. They found that, although there are considerable differences in the extent to which various cultural groups experience illusions, illusions are generally experienced. If, as has been repeatedly suggested (most cogently by Gregory 1973), such illusions arise because the figures that evoke them convey depth (that is, illusion-evoking stimuli are 2/3d) then clearly the universality of illusions argues for the universality of 2/3d perception of those figures that incorporate illusion-evoking elements. Segall et al.'s (1966) results also show cultural variation in susceptibility to illusions and therefore suggest that there are likely to be cultural differences in the intensity with which 2/3d figures are perceived.

Hence there is evidence of cultural differences in the way pictures are treated, even when they are correctly labelled. Such differences are confirmed by a comparison (Perkins & Deregowski 1982) between American and Zimbabwean children on a simple task of sorting real wooden blocks and representations of them. The two groups of children did not differ, it was found, when sorting the solids, but they did differ when sorting the pictures, although they did see them as pictures of blocks. These differences in the treatment of objects and representations are confirmed by a simple matching task and in more complex experimental situations. On a simple matching task, urban Zambian women of relatively little sophistication found picture–picture and object–object matching easier than matching pictures with objects (Deregowski 1971a). On a somewhat more complex task of learning positions arbitrarily assigned to a series of stimuli, Scotswomen performed better when the stimuli were familiar and real objects (such as a knife or a reel of cotton) than when they were easily recognisable pictures of those objects. When names of the objects written on cards were used as stimuli, performance was even worse (Deregowski & Jahoda 1975). A hint of cross-cultural differences on such tasks is present in Sigel's (1968; 1978) observation that children from a deprived background are less proficient at a Piagetian sorting task when provided with pictures than when provided with objects. In a later study Deregowski and Serpell (1971) showed that Zambian children performed about as well as Scottish children did when sorting objects, but significantly less well when sorting photographs of those objects. Analogous differences in the responses of Indian children living in South Africa were reported by Ramkissoon and Bhana (1982). It is commonly assumed that these difficulties arise because the pictures, in virtue of being pictures, share a unique attribute, and that objects, in virtue of being objects, have attributes not possessed by pictures (such as those affecting binocular perception of depth). That seems plausible, yet a part of the perceptual difficulty probably lies in the perceived *intent* of the stimulus. This is best explained by referring to Figure 17.

Figure 17 can be understood as showing an arrangement of two wire squares in parallel planes connected by a rod and standing vertically on a horizontal surface (Model A). It can also be taken to represent another wire model, two overlapping wire squares connected by a rod and lying flat on a horizontal surface (Model B). Subjects presented with Model A and asked to build a similar model almost inevitably build a three-dimensional facsimile. Subjects presented with Model B almost inevitably build a two-dimensional facsimile. Subjects who, when presented with a drawing, build a three-dimensional structure similar to that built in response to Model A, as many do, clearly recognize that the pattern (which is as flat as Model B) nevertheless represents Model A. They do so because they see the stimulus as a picture. The recognition of the background as flat, and therefore the picture as a picture, is crucial to the perception of pictures. This phenomenon has been extensively discussed by Pirenne (1970) in the context of the perception of pictures that give particularly strong impressions of depth, such as the famous ceilings painted by Pozzo. Pirenne referred to the observer's awareness of the perceptual significance of the pictorial surface as *secondary awareness*, a term derived from the writings of Polanyi (1958; 1970).

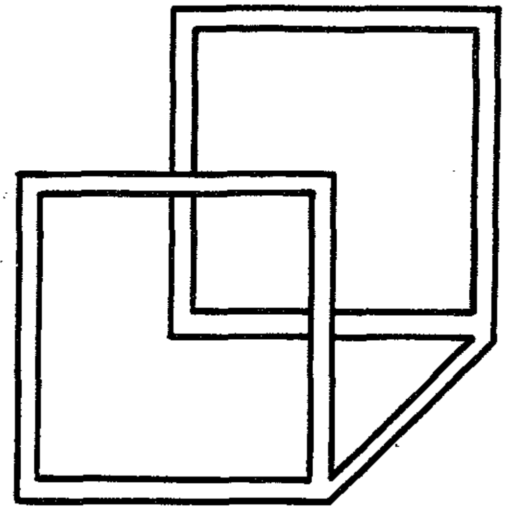


Figure 17. One of the drawings used as a stimulus in the Construction Task (Deregowski 1968b). The subjects were required to build the models represented using bamboo splints and Plasticine.

However, the effect described is not the only one responsible for the perception of space in pictures. Gregory's (1970) experiments with luminous models show that if a luminous flat Model B were presented to subjects in darkness and they were required to reproduce it, some of them would build a clearly 3D model, although they would not do so when responding to the same model in daylight.

Two factors therefore contribute to the recognition of such a figure as 2/3d, first, the flat background that indicates to the observer that the array can be interpreted as a 2/3d one, and second, the nature of the figure that ensures such an interpretation. The cross-cultural differences can accordingly have two sources.

The effect of the flat background has not, to this writer's knowledge, been extensively investigated; most workers direct their attention to the nature of the figure, focusing particularly on various representational depth cues. Yet the observations of Muldrow and Muldrow (Deregowski et al. 1972) and the extensive review of picture perception as a skill by Serpell and Deregowski (1980) both suggest that at least in some circumstances the background is the dominant factor.

To conclude: Picture recognition may involve not only identifying represented objects but also using pictures as if they were objects. However, one must bear in mind that it is fallacious to regard complete deception by a representation, as in the case of the primate who mistakes a picture of a spider for a real spider, as evidence of *picture* perception. Perhaps a skilled picture perceiver is

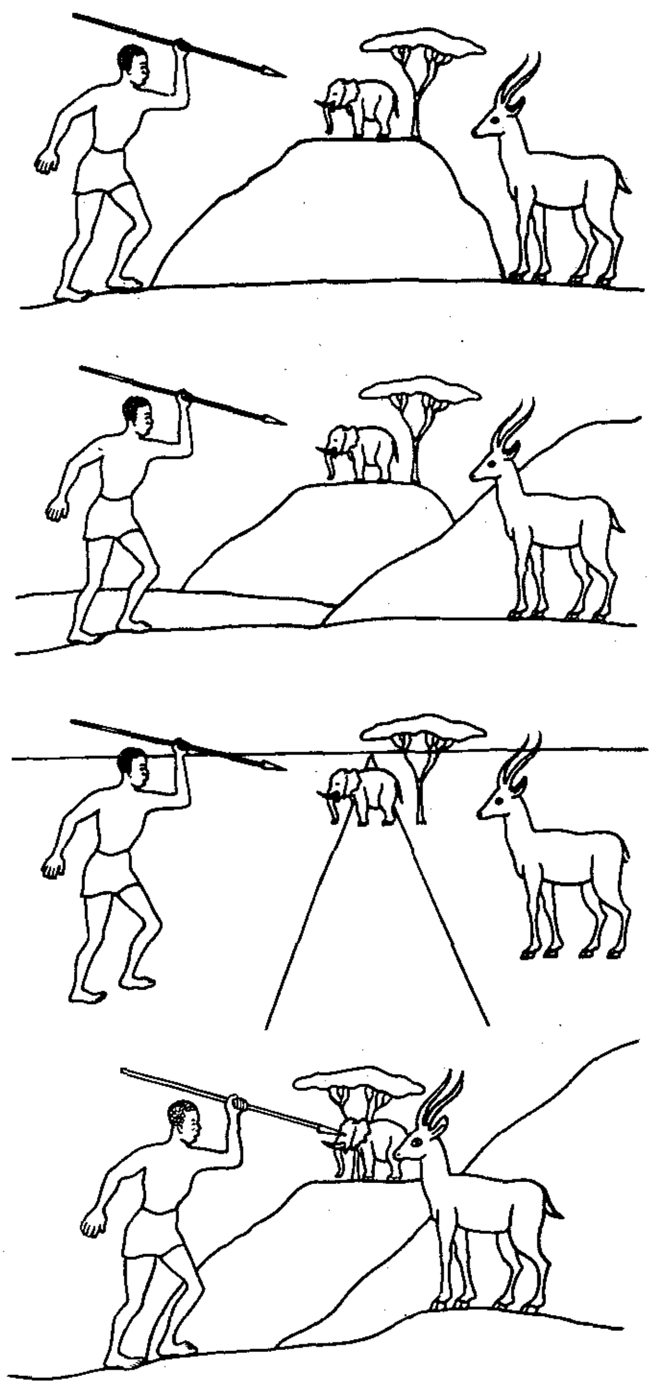


Figure 18. The first four of seven figures forming Hudson's (1960) test of picture perception. The subjects were asked to judge the distances between the hunter and the elephant and the hunter and the antelope. If they saw the former to be less than the latter, they were taken to lack the ability to see pictorial depth in the stimulus. Marked interpopulation differences were observed.

someone who can treat pictures perceptually as represented objects *when appropriate*.

7. Hudson's test and its applications

Although, as has been observed, difficulties in picture perception in a cross-cultural setting have been reported by a number of scientists in the nineteenth century, the earliest systematic investigations specifically addressed to this problem were those of Hudson (1960; 1962; 1967). Hudson was led to the problem by evidence that illiterate black mine laborers misperceived safety posters (this was subsequently investigated by Winter 1963) and by the very surprising responses they made to the Thematic Apperception Test (Anderson & Anderson 1964).

In his main investigation, Hudson presented a large number of subjects with a set of pictures consisting of six line figures and a photograph portraying a hunting scene (Figure 18) in which the hunter's spear is aligned, in the plane of the paper, both with the elephant and the antelope. The observer is asked a series of questions. To assess the use of 2/3i cues, observers are required to name all the objects represented (misperception of the elephant as, say, a cat, would nullify the usefulness of the picture for testing the perception of pictorial depth) and then to judge the distances in the picture (to assess the use of 2/3d cues). The crucial questions call for identifying which animal is the target of the man throwing the spear and which animal is closer to the man. If the man is described as aiming his spear at the "distant" elephant and if that elephant is reported as being closer to the man than the antelope then the observer is regarded as a "2D pictorial perceiver" on both scores.

The test pictures differ in the pictorial depth cues they provide. All depict differences in elevation and familiar size; two augment these with the cue of overlap and two with the cue of linear perspective (the road representation narrows as it recedes); and the photograph, which shows an array of models, also provides density gradients. The effectiveness of combinations of various cues can therefore be compared.

Hudson's seminal application of the test indicated marked cultural differences. His Bantu subjects tended to see the pictures as flat significantly more often than his subjects of European descent, whereas subjects of Asian origin formed an intermediate group. These results led him to speculate on the origin of the difference. His putative causes included a suggestion that the biosocial adaptation of the Bantu has led to relatively less differentiated visual perception in favor, perhaps, of auditory perception. This explanation gained popularity, but Hudson's findings also provoked criticism, much of it extremely trivial, amounting to claims that the drawings (which were admittedly poor in pictorial cues) were responsible for the effect simply because they were difficult to perceive. Few proper replications were attempted; 14 years later, Jahoda and McGurk (1974a), in their review of this work, found only one true replication. In other studies, either an abbreviated series of stimuli was used or the stimuli were so grossly distorted that they were parodies of the originals.[2]

Several attempts were made to produce test pictures retaining the essential features of Hudson's stimuli but incorporating changes intended to check on a specific feature of the design, usually the cultural familiarity of the stimuli or the effect of a particular depth cue. For example, Hagen and Johnson (1977) substituted a child with a ball for the hunter and two other geometrically similar figures of children for the elephant and the antelope. This introduction of similarity seems to be ill advised, because repetition of geometrically similar figures but of different size has, as Coren and Miller (1974) have shown, a profound effect on the perception of illusory size. Furthermore, one would expect the effect of similarity to be reinforced by presenting the elements at different heights within the picture (as in Hagen and Johnson's figures), because this creates an elemental Gibsonian gradient. It is therefore difficult to accept these modified drawings as perceptually equivalent cultural adaptations of the originals.

The outcomes of such modified tests may therefore not be comparable with Hudson's findings. Their use with populations other than those examined by Hudson is also questionable for a less technical but much more fundamental reason: Replications using modified and unmodified versions on other populations cannot possibly tell us how Hudson's populations would have behaved.

Yet another objection has been raised to Hudson's original study; that the results obtained from his sample of adult workers may be biased because the workers might have thought that they were being assessed by their employers (Dana & Voigt 1962). Because no evidence whatsoever is adduced for this hypothesis, it amounts to pure speculation. Moreover, it is directly contradicted by the data gathered by an anthropologist who administered Hudson's test to inhabitants of a northern Zambian village where she was well accepted and after she had lived in the area for over a year. Wong (reported in Deregowski 1980a) tested samples drawn from two tribes, Lamba and Bisa, and obtained the following proportions of subjects who were consistent 2D-perceivers (see discussion of Figure 16 in section 6 and Figure 18, section 7): Among men and boys 73% (N = 33) and 86% (N = 43), respectively; among girls 82% (N = 11) and 73% (N = 11), respectively. These results are consistent with Hudson's observation, and have serious implications for the use of drawings as a general means of communication but especially, as pointed out by Serpell (1974), in the context of education.

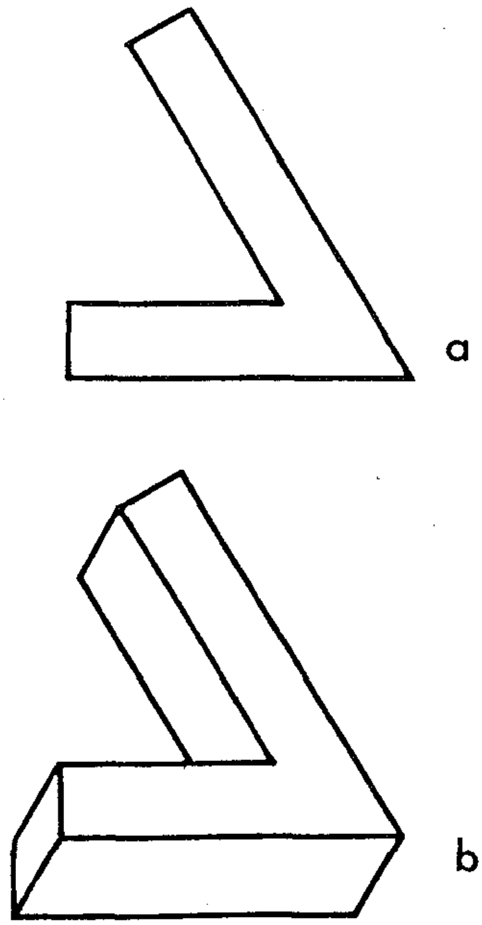


Figure 19. Two of the drawings to which subjects set the arms of wooden callipers used in the Kwengo Callipers Test (Deregowski & Bentley 1986). A subject who sees the bottom figure as depicting a 3D object is likely to see the angle between the represented arms as larger than that of the top figure.

8. Other measures of picture perception

It is unwise to rely on a single measure for such a broad concept as perception of picture space. This principle probably applies to the large majority of psychological concepts. A number of alternative tests was therefore used in cross-cultural investigations of the perception of 2/3d attributes of pictures, to which Hudson's work gave *impetus*.

One of these tests (the Construction Task) required subjects to build simple geometric models shown in pictures. Instead of making oral responses describing the perceived relationships in the stimuli (and in the case of the 3D perceivers, in the picture space) subjects were required to reproduce them in real 3D space.

One of the drawings used is shown in Figure 17. On the basis of whether the models built were three-dimensional or flat it was inferred whether or not the subjects had perceived the pictures as having depth. The same subjects were required to respond to Hudson's pictures. Although the tasks differed in difficulty (Hudson's test being harder), the results did appear to be related; those subjects who were judged to be 3D responders in Hudson's test were also, almost inevitably, judged to be 3D responders in the Construction Task, because they built unambiguous 3D models (Deregowski 1980a).

It has been argued (Gregory 1965; Segall et al. 1966) on the basis of studies of geometric illusions that certain configurations of lines are likely to be seen in 3D. Stimuli incorporating such configurations of lines are likely to be perceived as 3D (that is, they are 2/3d) when other stimuli, such as those of Hudson's test, are not. This conjecture is in agreement not only with the results provided by the Construction Task, but also with those obtained using an entirely different task (Deregowski & Bentley 1986) involving the same "geometric" principles: Subjects must adjust simple callipers, made of square timber batten, to indicate the angle made by the main lines of figures such as Figure 19a and b. The angle of the examples shown is clearly the same, but it is not seen as the same by those observers who see (a) as being flat (it could not possibly be seen otherwise) and (b) as 2/3d. Responses to such figures can therefore be used to assess 3D perception of pictures. The task is simpler and quicker to administer than the rather cumbersome Construction Task. It is also readily explicable to populations having little pictorial sophistication. Populations found untestable with Hudson's test are likely, the results suggest, to be testable with the Kwengo Callipers Test. Reuning and Wortley (1973) attempted to test Bushmen of the Central Kalahari using Hudson's test and were not successful; they attributed their failure to the "unfamiliar style" of the stimuli. In contrast, children of the !Ku and the Kxoe Bushmen of the Northern Kalahari were both consistently capable of 3D perception when tested on the Kwengo Callipers (that is, they saw [b] as 2/3d).

There were also significant differences among groups of children, the Kxoe being more prone to 2/3d perception than the !Xu. Zulus formed an intermediate group not differing from either of the two Bushman samples. Because the Zulus were drawn from a preschool center in a major city, the result questions the assumption that environmental exposure and school are inevitably the dominant influences on pictorial perception.

Patterns that evoke illusions associated with perception of depth are not necessarily perceived as depicting depth (2/3d), however. Newman (1969) has convincingly demonstrated that although Western 6-year-olds perceive the illusory effect induced by density gradients, their verbal descriptions of the scene show that only a quarter of them perceive it as depicting depth. All Western 10-year-olds, on the other hand, perceive both the illusion and the depth. This finding raises an important point; one must decide, in examining the results obtained using diverse procedures, whether they reflect true depth perception (i.e., 2/3d) or merely an illusory effect associated with depth but not associated with its "proper" interpretation. Thus, the relative exaggeration of the perceived size of the more elevated of the two geometrically similar figures (as occurs in the Ponzo illusion, Figure 8) does not necessarily imply that that element is seen as being farther away. That affects the interpretation of Jahoda and McGurk's (1974b; McGurk & Jahoda 1975) studies, which involved two steps: training and testing. The subjects were trained on pictures showing two figures, similar to those shown in Figure 20: one large woman and one small girl, both drawn with their feet at the same distance from the bottom of the picture. Subjects were required to place wooden tokens on a board in front of them. These tokens were of two sizes and could be placed two at a time on any two of the four corners of a rectangle marked on the board. In the case of the training picture, the correct response was to place a large token opposite the "woman" and the small token opposite the "girl" both at the same side of the rectangle, thus showing awareness of the representation of coplanarity. The picture used for testing (Figure 20) showed both figures at different pictorial depths. These were indicated by the relative height and size of the figures and stressed by the introduction of density gradients.

The test was administered together with Hudson's test (Figure 18) to Scottish and Ghanaian children. There was a significant difference between the two groups, the Scottish responses being consistently more 3D on both tests, although this difference was greater on Hudson's test. In addition, the scores of both samples were higher on Jahoda and McGurk's task than they were on Hudson's test. The pattern of results obtained here is strikingly similar to the results obtained in the Construction Task (Figure 17). In their interpretation of these results Jahoda and McGurk suggest that their task measures perceptual skills that, unlike the skills called for by Hudson's test, are acquired relatively early in life. This, it is postulated, explains why there is a significant increase of scores with age on Hudson's test and not on Jahoda and McGurk's. The increase with age/schooling is not uniform in both

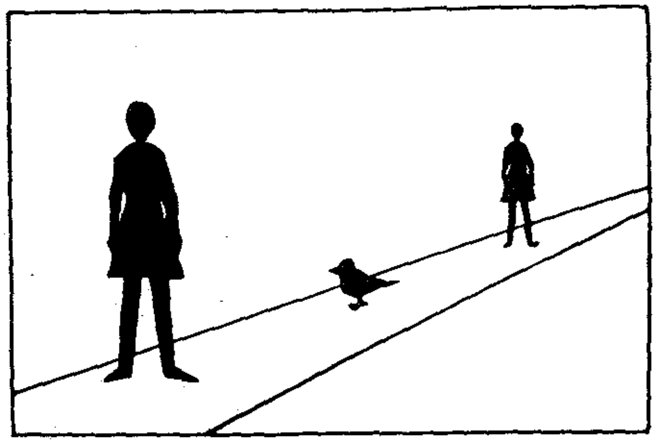


Figure 20. One of the pictures used by McGurk and Jahoda (1975). Subjects were required to indicate perceived position of the two manikins by placing tokens on a response board.

samples, however; Ghanaian pupils from second and fourth grades of primary school do not differ in their scores but those from fourth and sixth grades do, whereas the Scottish sample shows a steady increase throughout the range. The data could therefore be said to show that Hudson's test is inherently more difficult, so children who have reached the "ceiling" on Jahoda and McGurk's task may still be at the "floor" level in the case of Hudson's test. Such an argument is not acceptable to Jahoda and McGurk, however, who suggest that there is a qualitative difference between the two tests: Hudson's test "taps merely one specific aspect, and probably not the most important one, of a complex cluster of abilities."

It could also be argued (and this argument seems to be the more parsimonious) that the stimuli of both the Construction Task and Jahoda and McGurk's task involve geometrically similar elements placed at different heights in a picture; hence, both partake of the elevation effect, which is independent of the 2/3d value of the stimuli, but which has much in common with the Ponzo effect (Figure 8) just discussed.

One can probably measure pictorial depth most directly and convincingly with an apparatus developed by Gregory (1968) known as Pandora's Box. It relies on binocular judgement of the distance of a point of light that is seen as moving orthogonally to (and through) the picture's surface while the picture is viewed monocularly. Gregory used this apparatus to measure the effect of the Müller–Lyer illusion and Deregowski and Byth (1970) used it to compare the perception of two of Hudson's pictures. The results confirm our warning that verbal responses interpreted as 3D are not necessarily confirmable by perceptual judgements of distances within pictorial space. Thus, neither relatively sophisticated Europeans, who would have been expected to give 3D responses to both of Hudson's figures, nor Africans drawn from a population likely to yield 2D responders perceived Figure 18a as 2/3d. On the other hand, the two groups did differ when responding to Figure 18b. The Europeans, unlike the Africans, saw the elephant as significantly further away from the other two figures in the picture.

These results confirm that there are cross-cultural differences in the perception of pictures and, in combination with the results obtained by Newman (sect. 8, para.

6) and already described, they also show that: (1) It is possible for subjects to perceive 3D illusions in representations even when their verbal responses show that they do not perceive the spatial properties and (2) verbal responses indicative of 3D perception need not be associated with the experience of illusions as measured by Pandora's Box. When verbal indicators of 3D perception are not confirmed by performance measures, the responders are presumably guided primarily by their knowledge of pictorial conventions, which, although derived from the experience of the real third dimension, are in the particular case too weak to evoke the illusory effect. When the illusion is perceived but its effect is contradicted by the verbal response, the responders are presumably incapable of handling pictorial cues, possibly because of the inherent conflict between the monocular and the binocular cues offered by the figure or even because of contradictions among monocular cues. A true 3D perceiver of a particular picture should therefore be defined in terms of *both* elements: perception of the illusory effects and recognition of them as indices of 3D (i.e., the picture is seen as 2/3d). Hence neither the European nor the African subjects could be classified as 3D perceivers on the basis of the results obtained with the first of the two stimuli in the Pandora's Box experiment.

It was noted earlier that the responses of the two-pronged trident, which were thought to measure 3D perception, do in fact measure the ability to integrate elements that are each seen as three-dimensional (as 2/3d); there are cultural differences in the facility with which integration is achieved. Similar differential interactions among picture elements are reported in Makanju's (1976) studies of implicit shape constancy with children drawn from two Nigerian schools, one serving the academic personnel of the university and the other a population of a working-class suburb. The subjects were required to identify a simple geometric figure that appeared either in isolation or on a background of a drawing of a cube. Children of academics were more influenced by the presence of the background cues than were children of nonacademics; the former, for example, chose a less squarish figure to match Figure 21a than to match Figure 21b. That could be interpreted in two ways; it could be argued that the subjects less prone to implicit shape constancy are those who fail to see the background "cube" as a three-dimensional solid or that they fail to relate the effect of the perceived three-dimensionality to the shape of the figure. It has been argued on the evidence provided by Young (Young & Deregowski 1981) and by the studies of illusions that the latter explanation is more likely. There is evidence, however, obtained from a sample of Ivory Coast Baoule schoolboys, that both effects may be present (Deregowski 1980a). Those boys who were relatively more influenced by implicit shape constancy are also those more likely to build three-dimensional models in response to geometric line diagrams.

It seems probable, therefore, that both effects – 3D perception of pictorial elements and extrapolation from such elements to contiguous pictorial elements – influence subjects' responses and that these combined effects are responsible for the differences between samples reported by Makanju and for the cultural differences, such as the greater proneness to implicit constancy effects of the Scottish than of either the Baoule or the Nigerian samples.

9. Segall, Campbell, and Herskovits's studies of illusions and their consequences

Unlike Hudson's studies, which were serendipitous in origin, Segall et al.'s investigations (Segall et al. 1963; 1966; Segall 1979) were explicitly designed to examine the effects of experience on visual perception and were a fruit of cross-fertilization between anthropology and psychology, the former holding that perceptual functions are affected by culture and the latter that they are universal to mankind. The problem was reduced to two, in principle testable, hypotheses that will here be called the *carpentered world hypothesis* and the *ecological hypothesis*.

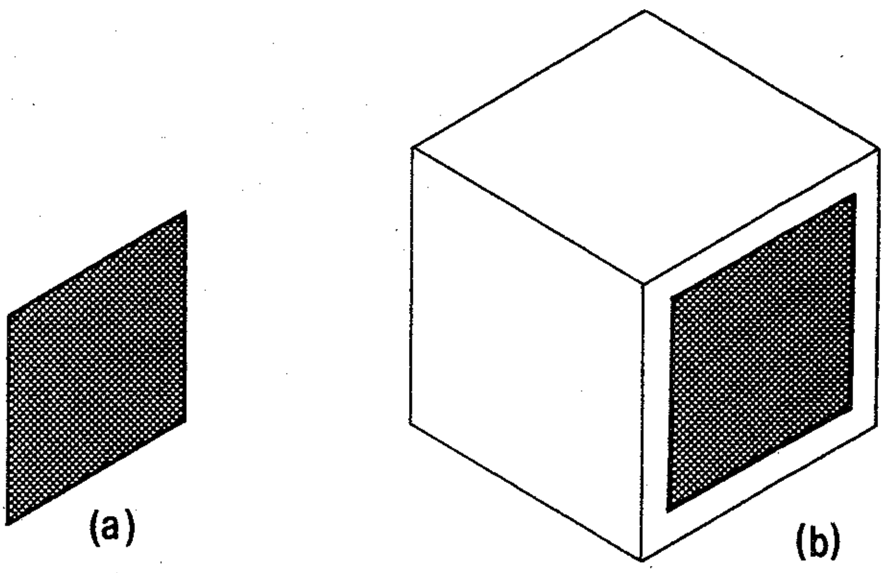


Figure 21. Stimuli used in implicit shape constancy studies. The two shaded rhombi are identical. Responses obtained in a shape-matching task showed that due to the implicit shape constancy, (b) was seen as more like a square than (a).

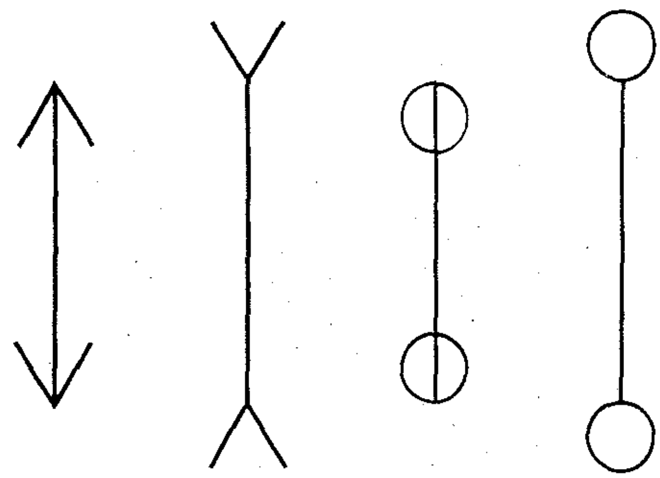


Figure 22. Two versions of the Müller–Lyer figure, the traditional (left) and a modified (right). The modified version removes the effect of angularity. In both versions subjects are required to judge the relative lengths of the vertical shafts. Within each pair those on the right are generally seen as longer.

These hypotheses were investigated using a very broad sample of both juvenile and adult subjects drawn from 16 culturally distinct populations, ranging from nomadic hunter–gatherers to urbanized Westerners and from inhabitants of open fields to townsfolk. The entire investigation is the most extensive of cross-cultural studies of perception hitherto undertaken and is meticulously presented by Segall, Campbell, and Herskovits in their book; only a rather sketchy outline of the rationale and the findings can be presented here.

According to the carpentered world hypothesis, subjects drawn from populations living in environments with many solid right angles are likely to perceive ambiguous representations of angles as right angles; when such representations are incorporated in figures that are even only vaguely reminiscent of the configuration of solid edges, such subjects are likely to see them as distorted in accordance with the expectations they would derive from solid edges. In contrast, subjects coming from noncarpentered environments are less likely to be prone to such misperceptions. The Müller–Lyer illusion (Figure 22) furnishes a convenient illustration of the effect. It has been suggested (and as far as the Western sample is concerned, demonstrated; Gregory 1968) that the tendency to see the right line as longer than the left arises because the former is perceived as further away from the observer than the latter. Observers from the less carpentered cultures are hence likely to be less prone to this effect than those from more carpentered cultures, whose constancy scaling is more responsive to the minimal angular cues the figures provide. (It ought to be noted that orthogonality of edges is not the only characteristic of the carpentered cultures that could have been exploited in order to evaluate the hypothesis; parallel edges could serve the same purpose. One would accordingly expect cross-cultural differences in the relevant perceptual effects already established in psychological laboratories, such as the tendency to see nonparallel lines as parallel (reported by Smith & Smith 1962), and the corollary tendency to see parallel lines as converging (ten Doesschate & Klystra 1955; ten Doesschate 1964).

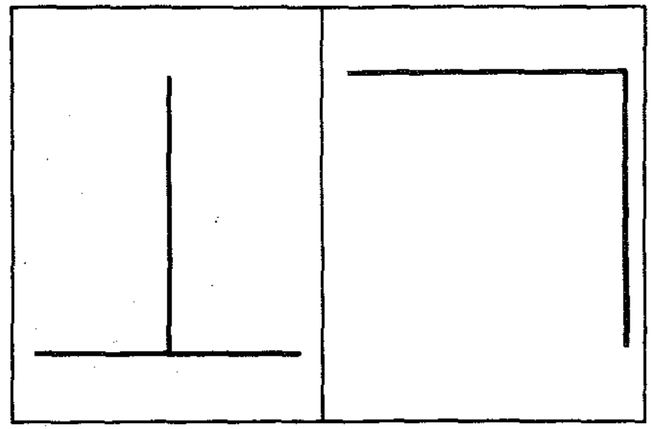


Figure 23. T- and L-forms of the horizontal–vertical illusion. The two lines forming each figure are equal. In both figures the vertical line is generally seen as longer.

According to the ecological hypothesis, inhabitants of open terrain (e.g., veld or desert) are more likely to interpret ambiguous linear stimuli as extending away from them than are the inhabitants of closed environments that confine the extent of their visual exploration (e.g., jungles or dense forests). The former will therefore be more susceptible to the horizontal-vertical illusion (Figure 23), because they will see the upright arm of the figure as extending away, and hence as longer.

The results obtained by Segall et al. (whose study involved a number of illusory figures; 1963, 1966) are of a kind frequently encountered in psychological research – they do not unambiguously indicate that particular hypotheses should be rejected, yet at the same time they do not warrant their enthusiastic acceptance. In short, they provide justification for further empirical work. Further work has accordingly been undertaken, both in cross-cultural and Western settings, and includes studies making use of test material designed by Segall et al. as well as specially devised materials. The issues investigated ranged widely. Davis (1970) concerned himself with the relation between literacy and the susceptibility to illusions of the Banyakole of Uganda (samples of this population were also used in the Segall et al. study). He compared groups differing in education, assuming education could be regarded as a single identifiable major factor, relatively independent of others. However, such independence is unlikely in a culture where education is not generally available and complex social factors determine the amount of education an individual is likely to acquire. The conclusions drawn by Davis support that view. His final plea is that such terms as "literacy," "carpenteredness," and "sophistication," which have been used by other workers in the area (e.g., Jahoda 1966; Segall et al. 1966) should be more precisely defined, a request that probably cannot be met without a degree of arbitrariness.

Another study by Davis and Carlson (1970) concerns comparisons of Banyakole subjects with those from the United States on two versions of the Müller–Lyer illusion and two types of instruction. The failure to find expected cross-cultural differences with one of the sets of stimuli again sounds a confused yet cautionary note; because it is not clear whether the observed effect is due to differences in the strength of the stimuli (as documented by Coren &

Girgus 1978) or the variation in the correlation between these figures and "carpenteredness." This finding is contradicted by another; Ahluwalia's (1978) study with two types of Müller–Lyer figures (Figure 22), one of the usual arrow form, and the other with circles instead of arrowheads. The latter form was judged by Ahluwalia not to have perspective cues. The subjects came from either an urban (and therefore carpentered) environment or from a rural (and therefore less carpentered) environment in Zambia. The results showed the expected difference between subjects drawn from carpentered and uncarpentered environments, and the environmental effect was therefore confirmed. However, there was also a greater illusory effect in both populations with the circle version than with the traditional arrowhead version. That seems to contradict the carpentered world hypothesis (because the figures not involving perspective evoke stronger illusions), and that interpretation is favored by Ahluwalia. However, it is equally plausible that the result has no relevance to the hypothesis because the two types of stimuli may involve unrelated perceptual processes, whose only common feature is that they lead to misperception of length. There is ample evidence of the confused relationship among the plethora of figures evoking illusions (Coren & Girgus 1978; Robinson 1972; Taylor 1974) to support such a hypothesis. It can therefore still be maintained that Segall et al. (1963; 1966) made a very judicious decision in choosing their stimuli, and that the perception of the Müller–Lyer figure does relate to the perception of space. Nevertheless, it cannot be denied that the cross-cultural studies of illusions are difficult to interpret unambiguously.

Some of the ambiguity of the results may derive from inherent difficulties in matching samples from populations that differ both genetically and in their exposure to particular environments, with individuals free to choose the environments they inhabit and the cultural artifacts they encounter daily. Studies that find differences between samples drawn from the "same" population but differing in lifestyle – e.g., differences between Australian Aborigines settled at a mission station and those leading traditional, nomadic lives (Gregor & McPherson 1965), differences between groups of Ghanaians (Jahoda 1966; Jahoda & Stacey 1970), or differences between the Temne of Sierra Leone and Canadian Eskimos as in Berry's (1968) ingenious studies – cannot control strictly for genetic differences. In addition, most such studies have chosen (presumably for reasons of convenience, but also perhaps swayed by the force that can be termed "inertia of replications") to test the hypotheses by using drawings. An uncalled-for variable was thus allowed to influence the measurement of an effect that is postulated to arise directly from the experience of space.

Studies of Leibowitz and his co-workers (Leibowitz et al. 1969; Leibowitz & Pick 1972) and that of Brislin and Keating (1976), which involved real three-dimensional stimuli, are notable exceptions and are especially important because, as we shall show later, they suggest a theoretical connection between group differences in the perception of pictures and the perception of space. All these studies used the same basic stimulus, the Ponzo figure (Figure 8). That is regrettable as far as the two hypotheses of Segall et al. (1963; 1966) are concerned, because that figure involves both postulated effects. The tendency to perceive converging lines as parallel may be derived either from the experience of a carpentered environment (the carpentered world hypothesis) or from the experience of parallel lines (edges of roads and paths) extending into the distance (the ecological hypothesis). Indeed such a combination of effects may have contributed greatly to the striking differences in the susceptibility to illusion among samples drawn from Uganda, Guam, and the United States and tested on a photograph showing converging lines as in the Ponzo figure (Brislin 1974; Leibowitz et al. 1969).

10. Illusion, constancy, and picture perception

The basic mechanism involved in the perception of such illusions as the Ponzo and the Müller–Lyer is thought to be constancy. There appear, however, to be no cross-cultural studies of the relation between constancy and susceptibility to illusion, although both phenomena have attracted researchers for a considerable time.[3] The studies just discussed suggest that any systematic investigation of these problems should examine the perception of real space as well as representational space. Not only should geometric illusions be studied with both "real" objects and pictures, but that should be paralleled by an investigation of real and implicit shape constancies.

Some relevant indirect evidence can be deduced from a comparison of Myambo's (1972) study in Malawi with Makanju's (1976) Nigerian studies. Myambo compared two groups of Sena men differing in education. The uneducated had, on average, two years of formal schooling; the educated had about 12 years and were university students at the time of testing. The procedure based on Meneghini and Leibowitz's (1967) study consisted of identifying an ellipse that "looked most like" an inclined disc (Figure 24). The results showed a clear disparity between the two groups, the uneducated being notably less affected by the slope of the circular pattern, just as the less sophisticated of Makanju's subjects were relatively less responsive to implicit shape constancy. These within-culture comparisons are paralleled by analogous comparisons between cultures. Myambo reports that her Sena subjects showed better shape constancy than her control group of educated Europeans; analogous discrepances were observed when Baoule children were compared with Scottish children (Deregowski 1980a).

The most ambitious cognate investigation is that of Stewart (1973). Here the apparatus used was a small portable model of the Ames room. The subjects, who were drawn from North America and from Zambia, were required to judge the sizes of pairs of rods displayed in the windows of the room; the differences within pairs of judgements served as scores. The scores of various subsamples of the Zambian sample, which differed in their exposure to the carpentered environment (*and* in their tribal origin), showed a trend consistent with the carpentered world hypothesis but too weak to be statistically significant. That result is as equivocal as those reported by other students of illusions (Berry 1971a; Brislin 1974; Dawson 1967a, 1967b; Gregor & McPherson 1965; Jahoda & Stacey 1970).

No differences were observed by Stewart between the American and the Zambian samples on the constancy

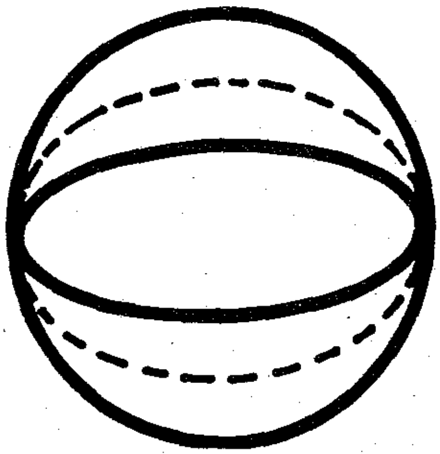


Figure 24. Schematic representation of notions involved in studies of constancy. When a circular disc, such as that forming the outer boundary of the figure, is presented to the observer at such an angle that its retinal projection is that of the innermost ellipse in the figure, subjects maintain that it looks neither like the retinal projection nor like the true shape, but like the intermediate shape shown by the dotted line.

task. That is a surprising result in view of the observation by Winter (1967) of finely graded differences in constancy among groups of different ethnocultural provenance, with Bushmen being clearly the best, and superior, in order of the magnitude of discrepancy, to both the European and the Bantu staff of a research institute, to Bantu locomotive drivers, and to European students of optometry (see also Reuning & Wortley 1973). Winter's results also show that the nature of the terrain in which Bushmen were given the constancy task affected the responses, the constancy being influenced by the structuring afforded by the amount of space separating the observer from the stimulus. That effect supported Ptolemy's ancient observation about the effect on the perceived size of the moon of having the earth in one's field of view. Intergroup differences in constancy were also reported by Mundy-Castle and Nelson (1962), who compared black laborers with white research workers and found that the former showed significant underconstancy; and by Van de Koppel (1983), who found that Biaka Pygmies of the Central African Republic (who are hunter-gatherers) misjudged the standard by a significantly larger increment than did their neighbors, the Bagandu farmers. Both the Pygmies and the Bagandu overestimated the size of the standard (and more distant) disc, but the Pygmies were more prone to do so.

Van de Koppel has also attempted to determine the relationship between size constancy and field dependence as defined by various measures designed, or inspired, by Witkin (1962). The relationship was originally thought to be that those who show a high degree of constancy are also likely to be strongly affected by the context and hence are likely to be relatively field-dependent. Subsequently, empirical data forced a radical revision of this hypothesis, suggesting that those observers who do relatively well on the Embedded Figures Test (i.e., observers who are relatively field-independent) are likely to be more accurate in judging the size of retinal projections than those who do not do so well (Witkin & Goodenough 1977). A battery of tests of field dependence was used by Van de Koppel and the scores on each were correlated with measures of constancy. Of the 20 correlations thus obtained (10 for the Biaka and 10 for the Bagandu sample), only 5 (all Biaka) were significant and such as to suggest that those who perform well on the constancy task are also more field-independent. The remaining 15 were nonsignificant – not a result that could be said to settle the matter unambiguously. Thus in this particular case, field-differentiation notions, firm and convincing as they appear initially, turn out to be rather weak on closer examination.[4]

The difficulty of determining the relationship between constancy and field-dependence probably arises because different perceptual skills can be used when judging constancies, some associated with field-dependence and some with field-independence. Two contrasting and unambiguous examples are presented below.

A subject observes the ratio of two pairs of objects (A, B) and (a, b) in his visual field, the judgement being performed within each pair and the results compared. When the ratios A : B and a : b are seen as equal, they are pronounced equal. That judgement is obviously extremely field-dependent; the sizes of the experimenter's discs (a and a, say) are assessed by considering them in relation to some other aspect of the environment (B and b). The relative distances of the compared objects are of no consequence; the judgement is made by comparing the objects to some chosen aspects of the field. That is presumably the kind of judgement made by subjects responding to the Ponzo figure where judgements of distance are not possible.

Alternatively, a subject may note the relative distances of the two stimuli and judge their sizes taking these distances into account. The judgement of the distances need not take into account elements in the visual field other than the two stimuli being compared; it may rely solely, for example, on binocular convergence, and therefore it may be independent of other elements in the visual field. Hence field-independent judgements of constancy are also clearly possible.

In practice, it is unlikely that such judgements fall exclusively into either of the two categories just described. Most are probably derived from a blend of these two elements, and whereas this blend may vary from culture to culture, its composition is not directly ascertainable and the results to which it leads do not correlate unambiguously with measures of field-dependence. The results of some of the cross-cultural studies therefore fall short of the expectations of the early studies of field-dependence such as those of Berry (1966; see also Witkin & Berry 1975).

11. The skills of perceiving spaces

Serpell and Deregowski (1980) have argued that the perception of pictures can be construed as a functionally specialised skill consisting of several components, the most fundamental of which is the ability to identify the circumstances in which other picture skills should be applied. The Mekan, who sniffed pictures, provide an extreme example of a failure in this basic component. Not only did they consider the application of picture skills inappropriate under the circumstances, but they did not even think that visual skills should be used to examine the picture. When one acknowledges that picture skills need to be used one must decide which of the elements in the visual field constitute the picture and then subdivide the constituent elements into those that provide the source of primary awareness and those that provide secondary awareness, that is, which elements of the perceptual input correspond visually to aspects of the represented object and which do not, although they still affect the way the stimulus elements are perceived. The relevant skill shades into that of coping with pictures that vary in their figure/background distinctness and in the extent to which they are "anarchic" – an ability in which those Kenyan subjects who claimed that the picture of the tortoise represented, say, a snake, were notably deficient.

The skills described so far are necessary but not sufficient for 3D perception of pictures. This can only be attained if the 3D value of the impoverished depth cues, which pictures normally contain, can be recognised. As we have observed, this ability varies greatly between populations and for different stimuli; some 2/3i stimuli such as very schematic representations of faces (Deregowski 1984) or stick figure representations of men and animals (Figure 10) are particularly effective, as are some purely geometric stimuli (Figure 4). Yet the effectiveness of a particular representational cue need be neither absolutely nor relatively the same in all cultures; different cultures may attach different importance to different cues, not only because some of the cues (such as streaky lines to indicate movement) are highly conventionalised, but also because of the uneven weights given to various nonconventional cues. Duncan et al. (1973) showed that different combinations of the position of the page and brightness elicited different responses from South African black and white children. The former were more sensitive to the changes in the height at which figures were placed in pictures when the effect of brightness was absent; the latter were more sensitive to that cue when it was augmented by changes in brightness. Analogously, it has been found that Scottish and Zambian schoolchildren are affected differently by different orientations of a figure serving as a model for building Plasticine and bamboo structures (Deregowski 1980b). When Figure 17 was shown to Scottish children, most of them built a 3D model; when the figure was rotated through 45 degrees so that it became symmetrical about a vertical axis, most of them built a 2D model. No such change of 3D to 2D interpretation with change in orientation was observed in Zambian children.

The 3D nature of the represented object can be conveyed by incorporating in the representation a selection of cues from the range available; not all, only some, are needed to evoke a 3D percept. Three concurrent lines are sufficient, as Perkins (1972) has shown, to evoke a percept of a solid angle. Studies of impossible figures and of illusions confirm this striking ability of lines to evoke percepts (see also Kennedy 1974; Kennedy & Ross 1975) and to create 3D images in spite of the absence of other cues and the presence of contradictory cues furnished by the surface on which the picture is made. Density gradients presented in isolation can also evoke the perception of depth in pictures under these conditions and so can other representational cues (Blakemore 1973; von Fieandt & Moustgaard 1977; Hochberg 1978).

Differences in styles of art at different times and in different cultures also support the observation that not all cues need to be present. They involve, as Strzeminski (1974) has shown, variations in the use "of the faculty of vision," that is, differences in perceptual skills. Thouless (1933) and Beveridge's (1935) early cross-cultural studies showed a clear relationship between shape constancy measured in real space and the artistic styles of different cultural groups and suggested that art reflects characteristics of the perceptual mechanism; this supports Strzeminski's notion. Their studies do not enable one to decide whether, as Thouless thought, the nature of the perceptual mechanism is reflected in art or whether, as contended by Piotrowski (1935), observers acquire different perceptual characteristics by exposure to different styles of art; a view recently espoused by Kosslyn (1982). It is not important to decide this issue at present, for the notion put forward here is merely that the same perceptual skills are used in dealing with the real world and in dealing with pictures.

In the present context, Brislin and Keating's (1976) cross-cultural study of the three-dimensional Ponzo illusion is particularly important. It shows that subjects prone to that illusion in viewing pictures are also prone to it in viewing three-dimensional objects. That confirms that the same cues are processed, and in a similar manner, whether they derive from a solid or from a picture.

It is probably safe to assume that observers learn the relative importance of various perceptual cues in the context of real space, and that that learning is subsequently modified in experiencing pictures. Performance on tasks involving pictorial space must therefore depend on the similarity between that learned system of cues, as modified by experience, if any, with pictures and by the system of visual cues used by the draughtsman.

It is uncertain to what extent the selection of those cues depends on genetic predispositions and to what extent it is acquired, but it would seem rash to maintain that learning does not occur. Nor would it be reasonable to postulate that that learning is of the "all-or-none" variety, a cue being either learned or not learned; it is more likely that cues are ranked in terms of their perceptual importance. This view of the relationship between real and represented space agrees with Colomb and Dasen's (1986) Piagetian work (Piaget & Inhelder 1956). Their studies of the Baoule show significant correlations between performance on spatial tasks – namely, construction by means of tokens of scenes shown in pictures (such as a football game that had to be reproduced by placing small figures of players on a model football field) – and comprehension of representational space in drawings of village life. A similar procedure was used previously by Brown (1969) and by Jahoda and McGurk (1974b; 1974c).

The skills used in dealing with real space and those used in dealing with represented space must therefore overlap. Observers who perform well on real space (and that means all healthy adult observers) will also perform well on picture tasks that can be accomplished with the skills appropriate to the perception of real space. For example, the perception of certain illusions such as the Ponzo (Figure 8) or the Müller–Lyer (Figure 22) involves the immediate transfer of 3D spatial skills into the realm of pictures. On the other hand, failure by observers from certain cultures to perceive the angles of represented solids correctly even though they correctly perceive angles of real solids (Perkins & Deregowski 1982) shows that that requires specific picture skills falling outside that shared area. In the case of observers drawn from cultures in which pictures are extremely uncommon (e.g., Fortes 1940; Hudson 1960), no picture-only skills will be available; hence problems calling for such skills will not be soluble. Because the 3D spatial skills are certainly, in some measure, learned, they are likely to vary with each other, not yet precisely defined characteristics of populations such as their genetic characteristics or their environmental experience. Such variation would almost inevitably lead to differences in the extent to which the spatial skills acquired in real space are adequate for processing represented space.

A simplified version of the postulated relationship is shown in Figure 25. Of the two solid overlapping circles, one depicts skills that could be used by an observer in the real world, and the other depicts skills that would enable him to make optimum use of pictures. The area of overlap of the two circles symbolises the body of skills shared by the two realms.

Skills of any individual or group are represented by a region within the diagram. Such a region (e.g., region A) can fall wholly within the area of 3D spatial skills such that it does not overlap with picture skills. That region corresponds to skills that are useful in real space but that cannot be exploited when dealing with pictures, for example, the skill of judging distance by using the difference between the two images that an object projects onto the two eyes (binocular disparity). An individual or group having only such skills would be able to perform well in 3D space but would not be able to process pictures.

Normally one would not expect the acquisition of 3D

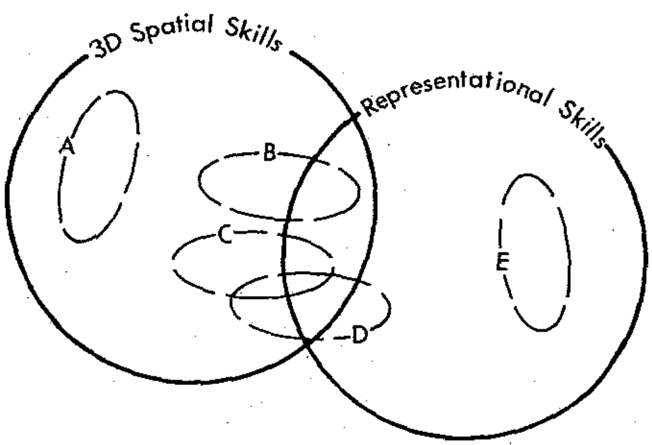


Figure 25. Schematic representation of spatial and representational skills. The regions enclosed within dotted lines represent various combinations of skills an individual may have. Region A contains only 3D spatial skills of the kind that are quite distinct from representational skills used in dealing with the 3D world (e.g., using retinal disparity to judge distances). Regions B and C contain 3D spatial skills, some of which can be used in the perception of pictures (e.g., interpreting overlap). Region D contains, in addition, skills that are purely representational (e.g., interpreting multiple representations as depicting movement). Region E contains only purely representational skills.

spatial skills without the acquisition of some representational skills. The 3D spatial skill of using monocular cues such as "overlap" (when one object is seen as overlapping another, the overlapping object is closer to the viewer than the overlapped object) is used in real space, but because overlap can also be represented, that skill can also be used in picture perception. Skills of that dual kind are represented in the diagram shown in Figure 25 by the lenticular area shared by the two circles: the skills falling within regions B, C, and D all have that attribute. The extent to which the representational skills are acquired may vary, as shown by the differences among regions B, C, and D. Regions B and C show skills wholly confined within the 3D spatial skills area. One would expect the populations having skills represented by these regions to be susceptible, for example, to the Ponzo and the Müller–Lyer illusions (as those having skills in region A would not be). One would also expect differences in the extent of pictorial skills, the skills represented by region B being more pictorial than those represented by region C. Region D represents skills of a population that has acquired, in addition to 3D spatial skills, some purely representational skills, such as recognising that a multiple representation of the same object indicates movement. Region E represents a set of perceptual skills that can be learned from pictures only; these have no relation whatsoever to 3D spatial skills. Such skills, insofar as representation of space is concerned, would be those that enable observers to interpret the 2/3i figures as having spatial attributes, for example, to see a stick figure as a representation of a man.

The ease with which 3D spatial skills can be transferred to picture perception is also inevitably affected by the nature of the skills for which particular pictures call. Some of the perceptual skills on which an artist from a hypothetical culture whose skills are represented by region D would rely when painting a picture would be the same as those of an observer from a hypothetical culture having skills represented by region C. Those skills, represented by the overlap between regions C and D, may make the picture understandable to both the artist and the observer. On the other hand, the observer whose skills are represented by region B, which has no overlap with region D, may find the picture incomprehensible, or may understand it differently. In consequence, the understanding of pictures may differ; one observer may see a picture as, say, both 2D and 3D and the other as only 2D, not perceiving the represented space; or one observer may even perceive a 3D figure where the other sees only a blotch. Thus the same picture may be variously seen as 2D, 2/3i, 2/3d or as a meaningless blotch. That effect need not be confined to different contemporaneous cultures; it is also observable in what is regarded as the same culture but at historically different periods. It is strikingly present in both the differences and similarities between mediaeval and modern pictures (Deregowski 1984). Its roots can be traced to the choices of style made by people with little or no experience with drawing (Fortes 1940; 1981).

It follows that poor understanding of representational space may either be a consequence of lacking purely representational skills or of limited expertise with real-space skills relevant to picture perception. Such a limitation may arise as a result of lack of exposure to appropriate stimulation (as assumed by both the carpentered world and the ecological hypotheses), but it may also arise from a historical cultural choice, the origin of which may be entirely obscure. Perceptual tasks, like motor tasks, can often be performed equally adequately in several different ways, and different means of achieving the same end may flourish in different groups. Danish and Scottish knitters, for example, using identical needles and knitting identical patterns make different use of their muscles and perform entirely different movements (personal communication from a Danish knitter living in Scotland).

When the skills habitually used in dealing with real space and with pictures are the same, as is the case with very skilled engineering draughtsmen (Spencer 1965), both spaces are treated in the same way (drawings are understood as easily as models); when they are not, discrepancies occur.[5] Such discrepancies have attracted considerable attention in the popular literature (Barley 1986; Kidd 1905; Landor 1883) as well as in academic works on perception (Gombrich 1962; Pickford 1972). The phenomenon can best be described as the failure to perceive culturally alien stimuli. That failure may either be complete (as in the case of some of the Me'en nomads [Deregowski et al. 1972] and of a Negro bushwoman [Herskovits 1948], who failed to recognize that a picture represented anything, thus failing to use the most basic of pictorial skills) or, as is more common, the failure may be partial: The observer recognises a picture as a representation, but sees it differently from the way the artist intended. That is a common experience of Western observers on their first encounter with Oriental art; they recognize the objects represented (such as pieces of furniture) but regard them as having been drawn incorrectly, because to them they appear distorted (Figure 26). That also seems to be the experience of those brought up in an Oriental culture when viewing perspective drawings done in the West, as in the case of a Japanese scholar (described by Gombrich 1962), who first thought that a box drawn in perspective looked crooked but after time and experience with Western drawings began to regard it as correct. That discrepancy between perceivers drawn from the two cultures is a result of a different expectancy concerning a correct drawing. The Western observer expects perspective convergence, the Eastern one does not. Thus, in that instance the Western observer's perceptual skill is related more closely to the immediate experience of 3D space than that of the Eastern observer, whose skill is probably more "pictorial" in origin. That is not the whole story, however; it would be wrong to describe divergent perspective as a convention, because there are circumstances under which divergent perspective is perceived in the real space (Wyburn et al. 1964; Zajac 1961). Similarly, differences reported in studies of implicit shape constancy (Deregowski 1976; Makanju 1976) show that representations of shape are not seen as the same by different cultural groups. It can also be argued that many unusual artistic distortions derive from perceptual experience in 3D space, although such experiences may be rare (Deregowski 1988).

The notion of skills used above is, of necessity, global and general. Elementary components of such skills have not been widely studied cross-culturally, although an oblique approach to such skills is present in all the studies, beginning with Hudson's (1960). Hudson used stimuli differing in monocular cues with the tacit assumption that an increase in the number of such cues should improve performance. However, in the absence of thorough analytical studies it is impossible to say whether improvements were due to the cumulative effect of the cues or merely to the presence of some of the cues that were previously absent – or perhaps to interactions among the cues, none of which produced a similar effect in isolation. In short, the cues that form useful conceptual devices for describing visual stimuli may not be helpful in defining perceptual skills cross-culturally.

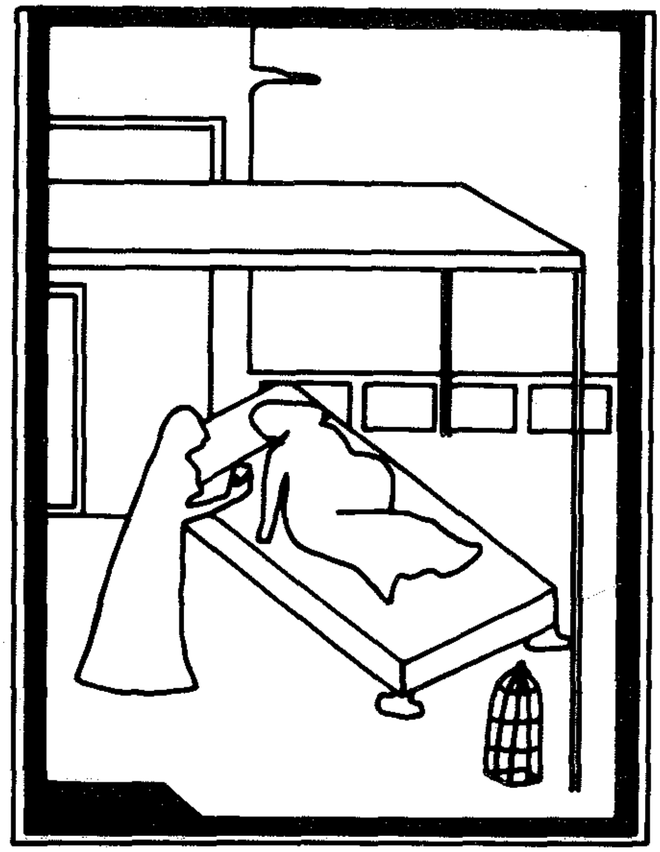


Figure 26. An outline of a painting showing distortions typical of certain Oriental artistic styles. The bed lacks perspective convergence and to some may appear distorted. For full reproduction of the original see Deregowski (1984, Plate 28).

There is a corollary to the attempt to interpret the ability to perceive pictures as a function of skills: Because all tests of representational perception are tests of skills, they may, like different artistic styles, involve different blends of skills, hence generating what look like incompatible results. One group of people may perform better on some test "A" than on some other test "B," whereas another group's scores on those two tests may be reversed. This kind of reversal is not unknown in cross-cultural studies when a broader range of skills is examined. It was encountered, for example, by Serpell (1979; 1985) when he compared English and Zambian children in drawing and making wire models. The English were better at drawing geometrical shapes and the Zambians were better at wire modeling.

12. A caveat and some practical implications

The imperfections of the cross-cultural data on which this target article is based have been repeatedly acknowledged in the course of this discussion. Available data do not allow us to evaluate the relative magnitude of genetic and environmental contributions to perceptual skills, nor do they permit an unbiased assessment of the effects of either education or maturation. Nor are data that could help to clarify some of these issues likely to become available. The words *culture* and *cultural* repeatedly used here are not used in a purist sense. They do not imply experimental control of the environmental and genetic effects, such that the variations observed could be said to be purely cultural. These two intruding factors were present in all the studies reviewed and may therefore have affected the findings.[6]

If, however, a more mundane justification than that given in the introduction is demanded for the work described here then it can be shown that, whatever the source of difficulties in the perception of representational space, these have been widely encountered in the real-life setting of institutions that train technicians, in professions that call for the ability to interpret diagrams, as well as in schools. Such difficulties are described by Guthrie et al. (1971), Agbasiere and Chukwujekwu (1972), and Bermingham (1976). These perceptual difficulties are especially acute in the case of students of mechanical engineering and emerge in the form of an inability to transform mentally (rotate, section, assemble) parts of machines. Davies (1973 and, following him, Deregowski 1974) attempted to devise a method of perceptual training using stereoscopic pictures. The most sustained efforts at finding an adequate method of teaching the perceptual skills needed to comprehend spatial representations and to perform some of the mental transformations described above were made by teachers of chemistry whose students must use complex diagrams of molecular structures. The findings have been published in a number of papers (Nicholson et al. 1977; Nicholson & Seddon 1977; Mitchelmore 1978; 1980a; 1980b; Seddon 1985; Seddon, Einaiyeju & Jusho 1984; Seddon, Tariq & Dos Santos Veiga 1984); all show considerable differences in pictorial skills among students drawn from various cultures and suggest that students from some cultures may find it particularly difficult to understand diagrams.

Recently, Dziurawiec and Deregowski (1986) used industrial workers having little or no formal education in an attempt to elucidate the nature of perceptual difficulties with pictures on the assumption that such difficulties are likely to be particularly acute in these subjects. The subjects were required to build representations of cubes. The findings showed a considerable range of difficulties, extending from failure to recognize the number of cubes represented to difficulties concerning their mutual spatial relationships. The former took the form either of omitting some of the represented cubes or, rather more strikingly, including supernumerary cubes in a way indicating unmistakably that some of the faces of the represented cubes were taken to be cubes in their own right; the latter took the form of mistaken orientation and placement of the cubes. (For illustrations of these responses see Figure 11, Deregowski & Dziurawiec 1986). This work shows that there are both practical and theoretical implications in cross-cultural investigations of real and represented space.

13. Conclusion

It appears that cross-cultural studies of real and represented space extend our understanding of perception primarily by demonstrating that the range of magnitude of the various phenomena is much greater than is suggested by studies conducted in Western cultures (the traditional source of psychological data). In the extreme cases these studies show that phenomena likely to be dismissed as marginal aberrations unworthy of closer examination when encountered in a "Western" laboratory and as merely anecdotal when reported by anthropologists have broad theoretical implications. Not surprisingly, assumptions derived from the psychologist's own culture dominate the psychologist's thinking. For example, an experienced experimenter working with nursery school children in the United States did not think of the possibility that pictures may not be effective substitutes for objects in a sorting task. Later, he demonstrated convincingly that the children found it more difficult to respond to pictures (Sigel 1968), yet his important findings have yet to enter the mainstream of psychological thinking.

Cross-cultural comparisons reorder the relative importance of some psychological phenomena and the perceived relationships among them. This brings out theoretical juxtapositions of phenomena that are not generally juxtaposed in the "Western" tradition but studied, as it were, in isolation. For example, studies of illusions and of pictorial perception have generally been treated separately in the West. Cross-cultural comparisons, on the other hand, promote the study of the role of illusions in pictorial perception and encourage the examination of pictorial perception as an interesting case of the use of the visual system for purposes other than those dictated by the circumstances in which it originally developed. Such an examination of the relationship between perception of real and represented space involving the concept of perceptual skills has been presented above.

By, as it were, "enlarging" the phenomenon, cross-cultural studies of picture perception also enable one to analyse it more incisively. Pictures should not be regarded as forming a unified category in which individual instances differ merely in the quality and quantity of the monocular cues (Blakemore 1973); rather there exist two distinct kinds of pictures. One kind is responsible for 2/3i perception and includes such forms as stick figures; the other is responsible for 2/3d perception and includes figures that are immediately seen as three-dimensional. The two kinds of representation seem to involve different processes. The former can be thought of as an attempt to *describe* nature and probably constituted a step towards pictographic writing; the latter is an attempt to imitate nature by providing a kind of stimulation similar to that derived from real space. Most pictures blend 2/3i and 2/3d characteristics, but the distinction provides a useful framework.

The perceptual skills acquired in real space are not as useful in dealing with the 2/3i pictures as they are in dealing with the 2/3d pictures. The explanation of differences in picture perception abilities in terms of the skills used in real space cannot be easily extended to 2/3i pictures. This form of perception appears to have some other origin that still remains obscure although it is clearly important and theoretically interesting; there is as yet very little evidence on the perception of such figures.

The findings call for a theoretical explanation of the difficulties that picture perception presents to some populations, especially in the representation of space. Unexpected difficulties may be experienced in some cultures when pictures are used as the means of communication in areas in which they have a well-established place in Western cultures (e.g., engineering or architecture). For example, students of engineering may, in some cultures, find great difficulties in comprehending represented space. The evidence clearly shows that pictures may not necessarily provide infallible means of cross-cultural communication.

ACKNOWLEDGMENTS

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NOTES

1. Although the Gibsonian model that provided the framework for her discussion (Gibson 1971) was later modified (Gibson 1978; 1979), these modifications do not affect the issue in question.

2. This evaluation of the use made of Hudson's test is contradicted in a contemporaneous paper by Hagen (1974; 1980), who maintains that the test had been used repeatedly. Hagen is in error here.

3. The earliest cross-cultural studies of illusions are probably those of Rivers (1901; 1905) and of shape constancy those of Thouless (1933) and Beveridge (1935).

4. This critique does not apply to the notion of differentiation in general; studies of other aspects of perception (which fall outside the scope of this paper) conducted on the same populations by Annis (1980) do suggest that the concept is a useful one.

5. It is apposite to note here that the early cross-cultural studies of picture perception were sometimes received with extreme suspicion; it was thought that the studies showed that those "defective" on a particular picture perception test were poorly suited for survival in the real world. Such an interpretation involves at least two errors; its protagonists assume that the same skills, and only the same skills, must be appropriate to perceiving representational and real spaces, and they also postulate primacy of the skills associated with representational space.

6. Certain areas of investigation have been completely excluded because, although they are important, they are marginal to the theme that is being developed here. Three of these areas, each of which merits a review of its own, are cross-cultural studies of art and aesthetic perception, of spatial memory, and of facial recognition.

A lively introduction to the first of these is presented by Anderson (1979), who lists key anthropological and ethnographic literature on the topic. There are relatively few purely psychological investigations, such as that of Binnie-Dawson and Choi (1982), which concerns perceptual and cultural cues in Chinese and Western paintings.

The problems of spatial memory have long attracted the attention of cross-cultural researchers working in Africa (Nadel 1939/1946; Cole et al. 1971), and recently also of a number of Australian workers, who have carried out systematic studies of the recall of spatial position of objects placed on a rectangular matrix, Kim's Game (Kearins 1976; Klich & Davidson 1983). These studies demonstrate that Aboriginal desert children are better at the game than their white counterparts. Unfortunately, there is no evidence as to whether this difference in the use of spatial information correlates with other spatial skills. Berry's (1966; 1971b) diverse psychological tests on the Eskimos (e.g., Visual Discrimination, Kohs's Blocks, Embedded Figures, and Raven's Matrices) suggest that there might be positive intercorrelations, but such extrapolations are risky, because the Australian data show that even extrapolating from desert to urbanised Aborigines may be invalid.

Analyzing cross-cultural studies of the recognition of photographs of faces would require examining the postulate that face perception has special social significance and may involve specific neurological mechanisms (as suggested by the cases of prosopagnosia; Ellis et al. 1986). That topic is outside the scope of this paper. The issues in question have been dealt with in several recent studies (Bauer 1986; Brigham 1986; De Renzi 1986; Ellis 1981; Hecaen 1981; Shepherd 1981). Jones and Hagen (1980) have examined some cross-cultural studies of the perception of pictures of faces in cross-cultural context. Shepherd (1983) is a more recent review.

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The uncertain case for cultural effects in pictorial object recognition

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To Western eyes and brain the perception of outline drawings seems so immediate and compelling that it comes as somewhat of a surprise that any visually competent individual would have difficulty interpreting such imagery. Of course pictorial incompetence is also surprising on theoretical grounds, given that the interpretation of a 2D image in terms of a 3D world is exactly what we do when the 3D world is painted on our 2D retinas. So a form of picture/real-object *equivalence theory* is hardly radical.

Most image-understanding theories such as the one that I have proposed (Biederman 1987; 1988), Recognition-by-Components (RBC), would hold that the mechanisms we use to solve the inverse optics problem in viewing the real world are also used in viewing a picture. (The *inverse optics* problem is that an infinity of possible 3D worlds could have projected any single 2D image.) In particular, certain *viewpoint-invariant properties* (VIPs) of image edges – properties of image edges that do not change with slight changes in viewpoint – provide a direct characterization of the edge projecting that image. Examples of such properties are whether an edge is straight or curved, the type of vertex at the cotermination of two or more edges, the parallel and symmetric relations among edges, the approximate aspect ratio of a part, the concavities that allow ready segmentation of an object into its parts, and the relations among the parts (such as TOP-OF, SIDE-CONNECTED). Equivalence theory, of which RBC would be one example, does not leave much room for cross-cultural effects in picture interpretation.

But what should we make of the reports of pictorial *in*competence? (I will primarily confine my review to the identification of familiar objects, rather than to illusions, depth judgments, and so forth.) I examined two of the articles cited in the target article that were readily available in an edited perceptual journal for which the pictures were illustrated, sample size was adequate, and data on the individual pictures were presented. These were the articles of Deregowski et al. (1972) on the Lowland Me'en in Ethiopia and Kennedy and Ross (1975) on the Songe of Papua New Guinea. Both cultures reportedly have minimal exposure to pictorial art and do not inhabit carpentered (rectilinear) environments. On some of the pictures performance was excellent. This was particularly true for the younger Songe for almost all of the figures, and the larger figures for the Me'en. Of the 34 Me'en, 32 identified the picture of the leopard correctly. There were no errors on many of the pictures for the Songe. As both Deregowski and Kennedy and Ross (1975) note, the competence here squares with the Hochberg and Brooks (1962) report of an American child from whom pictorial materials were withheld until the age of 19 months. Nonetheless the child exhibited excellent pictorial competence.

We have, then, clear cases of individuals from pictorially restricted environments showing some pictorial competence. But we also have cases where some individuals reveal difficulty in pictorial interpretation. Although one might be skeptical of some of the historical reports reviewed by Deregowski, there were sufficient indications in the Deregowski et al. (1972) and Kennedy and Ross (1975) data to suggest that many individuals have trouble identifying *some* pictures. But are these primarily cultural effects in the interpretation of VIPs? The Songe revealed problems primarily with unfamiliar objects or objects that were largely defined in terms of texture or motion, such as a fire and a stream. The depiction of such motion may indeed be subject to artistic convention and hence not readily available to untutored perceptual systems.

More disturbing to equivalence theory was the finding that many of the Lowland Me'en exhibited great difficulty in identifying small, camouflaged objects, namely, an elephant and a tree in the background of the scene and a spear held by the man. The error rate on these objects was 67%. Although these objects require some scrutiny, Highland boys, who come from a more urbanized environment, could identify them perfectly.

What might be an explanation for such errors? Deregowski suggests that the Me'en have trouble in integrating the parts of the picture into a whole, but why would this problem be confined to the smaller pictures? If we can generalize from the Songe to the Me'en, the Lowland Me'en's difficulty is not a consequence of the objects' being presented together in a scene. The Songe were successful at identifying the individual entities in several such arrays. Moreover, the Me'en were able to identify the larger, foreground entities in the scene.

It would seem premature to conclude that there is a cross-cultural effect in image understanding without testing for visual loss. I tried this picture on a severely nearsighted individual, not wearing reading glasses. That person revealed exactly the same pattern of errors as the Me'en: Easy identification of the larger objects in the scene; an inability to identify the smaller, camouflaged objects. Consistent with a visual loss account was Forge's (1970) report of an improvement in performance of the Sepik of Papua, New Guinea, when he added thick outlines to his photographs and the dramatic decline in picture identification accuracy in Kennedy and Ross's (1975) older (40+ years) subjects.

Whatever the ultimate origin of these errors, I see little to support the carpentered-world hypothesis. The use of VIPs is also associated with a *regularization bias*. Given some uncertainty as to orientation in depth, edges that *could be* projections of parallel, symmetrical, or rectilinear arrangements in depth are interpreted as parallel, symmetrical, or rectilinear. The bias toward rectilinear interpretation of nonrectilinear edges is, if anything, stronger in individuals from noncarpentered environments, as assessed by Deregowski's own work (Perkins & Deregowski 1982) with rural Botswanese. I do not know why these results were not given greater weight by Deregowski in considering the carpentered-world hypothesis.

What about those individuals who have difficulties responding to a picture as an image? In one case, the subjects were reportedly more interested in the photographic paper (a foreign substance as Deregowski reasonably notes) than what was depicted on it. It is possible that this problem is also one of scale and location: An individual may attend to the whole object itself (the paper) rather than what is depicted at a smaller scale on the surface.

A methodological note: In addition to the need for vision testing, many of the competing hypotheses – such as an attentional effect in looking at the paper rather than the picture – posit difficulties that should be relatively easy to overcome with instruction. The benefits of such instruction or training should transfer to other pictures. On this account, it is somewhat remarkable that *no* studies were reported of the effects of exposure and feedback from previously presented pictures on the identification of subsequent pictures. Sophisticated designs are not really required at this point. One need only balance the sequence of pictures to assess such effects. Given the recent development of theories of image understanding, it would also be highly desirable if the design of the stimulus materials were motivated by possible theoretical accounts of the nature of the deficit.

I could find no convincing evidence from the research reviewed by Deregowski that individuals living in nonpictorial cultures require a different theory of image understanding from those in Western cultures. I do not know whether Deregowski would contest this conclusion.

Is pictorial space "perceived" as real space?

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Deregowski provides a broad review of cross-cultural data and then draws a number of distinctions between types of pictures and between sets of spatial skills. Despite the intriguing and provocative insights his data provide about spatial perception, however, some problems still remain with the articulation of certain pieces of his inventory, especially in regard to skills used for perceiving pictures.

Pictures are distinguished according to whether or not they have direct three-dimensional cues: 2/3i pictures, which represent real space through differential processes, seem to be something like *signs* of real objects, and constitute a first step to pictograms. In contrast, 2/3d pictures attempt to *imitate* nature through an analogical process, and are on the way to *trompe-l'oeil* pictures; their perceptual properties, Deregowski claims, are, in some sense, like those of real visual scenes. In another sense, it is still the analogical function of pictures with respect to the real world that is the basis for distinctions among perceptual skills. Some skills, such as the interpretation of retinal disparity as a cue for depth perception, are related only to spatial objects; others, such as the representation of movement by multiple representation, are specific to pictures; the last category is common to both real and representational space.

Such distinctions are useful indeed. But one can ask whether such a taxonomy of skills and functions provides enough of a basis for a deeper understanding of psychological processes underlying space perception and picture comprehension. Putting together a collection of skills does not give us the slightest insight into the relationships that might hold among these skills. The examples given by Deregowski obviously rely on quite different kinds of processes, ranging from elementary mechanisms of visual perception to sophisticated devices of a "metaphoric" nature (cf. Kennedy 1982) that might be used, for example, in comic strips. The main claims of Deregowski's target article, however, bear on the common spatial features of visual and representative space. I shall focus on this point.

Deregowski's approach is essentially descriptive: His aim is to know *what* subjects are perceiving, not *how* they perceive it. Yet it may well happen that two skills that can be described as identical, insofar as their results are concerned, turn out to rely on quite different psychological processes. Deregowski himself gives an example of such a case, when he discusses apparently inconsistent results on the Muller–Lyer illusion; the same argument could be applied to his claim that 3D perception in pictures relies on the same processes as 3D perception in the real world. Conversely, are 2/3d cues in pictures really different from 2/3i? The study of picture production, which Deregowski does not take into account at all, can provide some insight into this issue. To study picture perception without studying picture production would be as big a mistake as studying language comprehension without language production.

Detailed studies of children's drawings, at least in Western countries, have shown (for instance, Caron-Pargue 1985; 1987a; Mitchelmore 1987; Willats 1984) that the use of oblique lines to represent depth cues does not occur as the mere insertion of 2/3d cues, which the child could not achieve formerly for lack of the necessary graphic skills. It involves, in fact, a reorganization of already acquired processes which aims not so much at giving a better account of the visual properties of the object, as at encoding a larger set of information about its intrinsic structure. Partial occlusion of one object by another ("hidden line elimination") appears to be the product of a similar process (Caron-Pargue 1987b). In every case, the emergence of graphic cues, which seem at first glance to rely on purely perceptual mechanisms, turns out, on a more analytic examination, to be the product of a progressive constructive process, controlled by the intrinsic "logic" of coding devices.

Moreover, the characterization of a given picture as 2/3i or 2/3d may sometimes be far from clear, if the picture is considered from the subject's point of view (even when it is clear to an external observer). Let us take the case of the drawing of a cube, conventionally drawn with oblique lines conforming to the "visual" 3D cues. Based on Deregowski's criteria, this is clearly a 2/3d picture. But 10-year-old subjects who must draw a cube with stickers put on opposite or adjacent faces produce a perfect 2/3d picture and make use of it as a 2D (or 2/3i?) figure in choosing the location for the stickers: Their placements rely on the relative position of the polygonal (2D) portions of the figure (Caron-Pargue 1985, p. 198). (See Figure 1.)

Representing the spatial properties of objects is not the same as perceiving them. Perception is largely a matter of automatic processes that can be thought of as modular and possibly innate (Fodor 1983). The interpretation of pictures appears as the product of a cognitively controlled construction, which – albeit eventually automatized – takes time and involves a mixture of individual inventions and cultural influences.

Why focus on picture production? Because picture perception is not mere perception. A picture is not a thing, nor a copy of

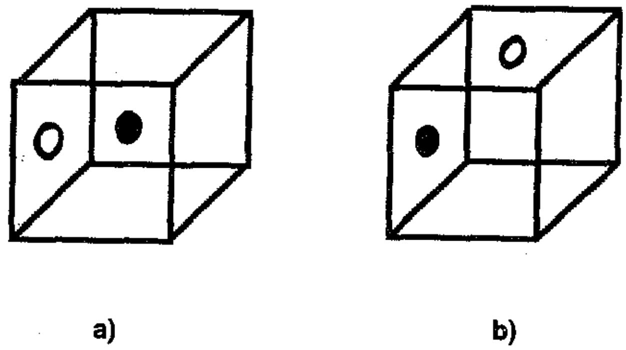

Figure 1 (Caron-Pargue). Ten-year-olds were instructed to label opposite (a) or adjacent (b) sides of Necker cube.

a thing: It *means* the thing it represents. Whereas visual perception is, so to speak, "wired into" our brain, picture perception is not. Picture interpretation must be acquired; it can in some cases be totally lacking, a notion Deregowski himself supports with convincing evidence. Like language, picture interpretation requires a kind of psychological processing that involves not only learning, but an essential interconnection between production and comprehension.

The issue is not purely theoretical. It has practical implications, as Deregowski points out in the conclusion of his paper. For example, training engineering students to understand and make use of pictorial representations does indeed, require a deeper understanding of the psychological processes involved. But in order to achieve such a task, a mere inventory of superficially similar "skills" is not sufficient. A more promising way seems to be to search for *differences* between these skills and for a more precise characterization of the psychological processes that underlie them.

Cross-cultural studies of visual illusions: The physiological confound

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As Deregowski points out, there is a long history of the use of visual-geometric illusions as tools to study cross-cultural differences in picture processing. Illusions seem to have certain inherently appealing characteristics in this context. First, because they generally involve relatively meaningless stimuli they are less likely to be confused with object identification factors or stylistic traditions. Second, the observed distortions are not very well known among the general population, hence they are not subject to response biases based on expectations or cognitive set effects. Finally, with pictorial material the data often take the form of responses that must be coded into nominal categories (based on items identified or three-dimensionality noted), whereas responses to illusions can produce quantitative measures denoting the *degree* of distortion perceived by the observer.

The most common explanations for cross-cultural differences in the perception of illusions refer to experiential factors. They include exposure to particular patterns of depth cues (e.g., *ecological theory* and the *carpentered world theory*) or factors associated with prior exposure to graphic and pictorial representations or with educational factors (see Coren and Girgus 1978a, 1978b, and Deregowski's target article for reviews). Although such explanations are appealing, closer scrutiny demonstrates that they are incomplete. Their major shortcoming is that they ignore a number of physiological variables that are intertwined with the cultural factor and that can also predict cross-cultural differences in illusion magnitude.

Many studies have shown that cognitive factors alone are not sufficient to explain the existence of many visual illusions. Estimates vary somewhat, but physiological factors associated with optical and neural mechanisms in vision may account for approximately 40% of the magnitude of illusions involving converging and intersecting line elements, such as the popular Mueller-Lyer figure (e.g., Coren 1986; Coren & Girgus 1978a; 1978b; Coren & Porac 1983; 1984). Some of the specific physiological variables that contribute to illusion formation include optical blurring, light scatter in the eye, and contrast present in the retinal image. These mechanisms may interact with the genetically based biological characteristics of the subjects tested in such a way as to produce cross-cultural differences that have nothing to do with differential experience, as will be demonstrated below.

To understand how physiological mechanisms can produce some of the patterns of results noted by Deregowski, we must first point out that there is a spurious correlation between density of skin pigmentation and degree of urbanization observed in cross-cultural samples. Thus the highly urbanized North American and European populations used in cross-cultural studies tend to be Caucasian, whereas the nonurban, poorly educated samples that have been isolated from exposure to graphic materials are most frequently Negro or Mongoloid. Skin pigmentation tends to covary with pigmentation of the fundus of the eye, pigmentation of the crystalline lens, and pigmentation of the iris. This is important for our discussion because Pollack and Silvar (1967a; 1967b) were able to show that individuals with a heavily pigmented ocular fundus show reduced illusion magnitude, and that dense fundus pigmentation is more characteristic of Negroes than Caucasians. Iris pigmentation plays a role in illusion magnitude also. Coren and Porac (1978) were able to show that lightly pigmented irises, such as the blue eyes that are found in many Caucasian samples, allow more light to scatter in the eye and hence increase the magnitude of converging line illusions. Both Berry (1971) and Bornstein (1973) have reanalyzed existing sets of cross-cultural data and concluded that the susceptibility to some visual illusions is more highly correlated with skin pigmentation than with ecological and experiential factors.

Pigmentation is not the only physiological factor that varies with ethnic group and may influence illusion magnitude. For example, there is a good deal of evidence that uncorrected refractive errors, resulting in blurring of the retinal image, can increase some illusions (Coren 1969; Coren et al. 1978; Ward & Coren 1976). This becomes more important when one recognizes that there are also genetically based differences in visual acuity, with some groups, such as Australian aborigines (Taylor 1981), Eskimos (Woodruff & Samek 1976), and other native groups (Boniuk 1973) showing marked deviations from the Caucasian norm.

Another physiological factor to be considered is a genetic one. Most of the groups used as subjects in cross-cultural studies are relatively isolated. One result of this is inbreeding, which results in a high degree of genetic similarity among individuals. Much greater genetic diversity is found in larger, urban settings, or in more advanced countries with highly developed transportation systems that promote easier movement of the population. Coren and Porac (1979) have been able to demonstrate that susceptibility to some visual-geometric illusions is heritable. To the extent that this is the case, there is an inherent bias toward finding differences in the measured magnitude of illusions in inbred populations, compared with more extended populations with a larger genetic pool to draw on.

The findings reviewed above suggest that the use of visual-geometric illusions in cross-cultural research must be approached with a good deal of caution. One cannot simply ascribe cross-cultural differences in illusion susceptibility to experiential and ecological factors. Rather, one must recognize that important physiological factors also influence the responsiveness to illusion stimuli. At the very minimum, these data suggest that cross-cultural studies ought to keep extraneous factors, such as ethnicity and skin pigmentation, constant across groups, confining the variations to education, ecology, and measurable experiential factors. Any failure to do this will result in data in which physiological and cognitive factors are hopelessly confounded.

Variations in pictorial culture

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The figures painted on a Grecian urn are curved as the urn itself is curved, but the figures in the represented space of the urn – Aphrodite and Athena, say – are curved in an altogether different way. In a Renaissance painting of a façade, the flatness of the panel is not the flatness of the façade, and the façade's flatness would be as it is if painted instead in a majolica bowl. Whether the face of the white square in Malevich's "White on White" is coincident with the square of white paint with which it is painted –whether the latter *is* or *is of* a white square – is a decision that has to be made. Pictures have double identities and almost always contradictory essences: They are made of paint but of course what they are of, if human figures, is made of flesh and blood – and even paintings of paintings require a distinction to be made between the paint itself and the paint it is of.

What in the real world prepares us for entities of this double nature? What in real life prepared those Ugandans described by A. B. Lloyd (1904) for the picture of the elephant that materialized on the sheet he used as a screen in his magic lantern show? Real-life experiences with elephants doubtless prepared them to recognize the content of that frightening slide – and their responses were those an elephant as such might have elicited, unless their agitation were provoked by the "magic" of the magic lantern, as stunning to them as the magic whereby Prospero calls down spirits to entertain his daughter and her swain. Would they then have behaved with such excitement if the picture had been of something harmless – a baby, say, or something as simple as a ball? I can't tell whether they lacked the concept of a picture, or of a picture being made quite as effortlessly as the circumstances of slide projection entail. But even if a group has the concept of a picture, nothing in their pictorial culture might prepare them to recognize that a certain abstract shape (such as Figure 17) could be the subject of a picture and hence be in pictorial space rather on a surface as a decoration (Cf: "It's not an abstraction consisting of stripes – it's a realistic depiction of a striped surface.")

The pictorial culture of different groups may vary without their experience in real space varying much or at all. The Ugandans so explosively entertained by Lloyd were given an abrupt lesson in pictorial culture that set up a severe difference between those who attended the slide show and those who did not, as between the lives of those who were at the slide show before and after that event, without this reflecting any change to speak of in their perception of real space (they obviously needed no instruction in the pictorial recognition of elephants). The deep lesson would be that something can look just like an elephant and yet feel like a sheet, and have no more thickness than a shadow. For those who live in a picture-saturated culture, awareness of such thinness (like the awareness of the curves in Grecian urns) may be "secondary," to use Pirenne's (1970) term;

but it was primary awareness when the chief discovered that the elephant had no material body by peeking behind the sheet. And it stops being secondary too when we become art critics, and seek relationship between the properties of images in their physical embodiment and in their content. And when pictures are not a regular part of a culture, as with Hudson's subjects, awareness must vacillate between the two sets of properties. It is this rather than any pictorial incapacity as such that made their responses so unsatisfactory.

I conjecture that Hudson's subjects, like us, would have used the same word for the picture of something as for the thing itself: No parent is so pedantic as to correct the child who says "doggie" when shown a picture of one by saying "Wrong. It's a picture" (otherwise all the pictures in the picture-book would be the same). Under one use of the term "elephant," then, the elephant is between the antelope and the hunter, hence closer to the hunter than the antelope is. Under the other use, it is in a different plane altogether, forming the apex of a triangle with the hunter and antelope forming the other two. Nothing in reality can be between and not between two figures, so in which of its identities is the elephant being asked about? Would the subjects have been less confused had the figures themselves been less schematic – more 2/3d rather than 2/3i, to use Deregowski's notation? Hudson's drawings give me the creeps. Notice that the hunter is throwing spears with his left hand. Was this done? And notice that the two arms are in the same plane when the action requires them to be in different planes – so why should anything be in different planes? What shows that we have a landscape with three components rather than a concatenation of three schematic pictograms, as in a rebus puzzle?

In the "Tribute Money" of Masaccio, the same figure is painted three times, in three distinct poses. One knows or comes to know that of course there were not three lookalikes at that depicted moment in the Holy Land, but that the artist was showing three moments of a narrative in a single masterful image. In an Annunciation by Fra Lippo Lippi, the Angel of the Annunciation appears in the same space in which we see the Immaculate Conception transpire *and* we see the Virgin pregnant. We are shown all at once three moments in a tremendous drama that has to be understood diachronically or the painting collapses into blasphemy – the Angel telling a pregnant woman she is going to have a baby! These works were not confected for the cabinet of humanist scholars but were meant for spaces where quite ordinary Florentines came to worship. We have to undertake a special study to find our way around in Florentine paintings, but we would have little difficulty finding our way around Florence, were we somehow transported there. And Florence and its spatial reality can have altered but little before and after the discovery of perspective by Brunelleschi.

In Section 12, Deregowski cites studies that show "considerable differences in pictorial skills among students drawn from various cultures and suggest that students from some cultures may find it particularly difficult to understand diagrams." Understanding diagrams has to do with our powers of visualization – and visualization is a pictorial skill that takes us from images to real space, not the other way round. The differences, surely, are not between the spatial realities of different cultures, but between their different levels of pictorial culture. (It is an empirical question whether our powers of pictorial recognition diminish after a certain age, like our ability to learn second languages.)

If the pictorial space in which our experience with real space enables us to find our way around is defined in terms of real space, then Deregowski's thesis is trivial – otherwise it is false. In any case, the reason pictures "may not necessarily provide infallible means of cross-cultural communication" is surely because of differences in pictorial culture – and this just cannot be accounted for in terms of differences in real space.

Images, depth cues, and cross-cultural differences in perception

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I wish to question two concepts that seem to me to be central to Deregowski's position: his distinction between images with and without direct cues for depth, and his idea of cue recognition as a prerequisite for the perception of depth in pictures. In my view both concepts run into trouble.

Deregowski distinguishes between two-dimensional (2D) images without direct three-dimensional (3D) cues and 2D images with 3D cues. These are referred to respectively as 2/3i and 2/3d images. A black silhouette of an elephant and an outline drawing of a human figure (Figures 3a and 3b) are presented as examples of 2/3i images and an outline drawing of a truncated pyramid (Figure 4) as an example of a 2/3d image. It is contended that whereas 2/3d images may evoke the illusion of 3D space directly, 2/3i images do not. In the latter case the cues, presumably including familiar forms like an elephant or a human figure, lead indirectly to the recognition of a 3D object.

This distinction between two classes of images can be questioned on two grounds. First, cues for depth are many and often subtle and may pass unnoticed in even simple figures. This appears to be the case in Figures 3a and 3b. A likely cue for depth in the silhouetted elephant is the different elevations of the feet: The two far feet are higher in the visual field than the two near ones. Gibson (1950) showed that elevation in the visual field is a potent cue to relative depth. He did so by cleverly arranging two objects so that the physically nearer one was more elevated in the field than the physically farther one. In consequence, their apparent relative depths was the reverse of their physical depths. The same point can be made about the Tallensi drawing of the human figure in Figure 3b. The left foot is clearly higher in the field than the right foot and the left hand is higher than the right hand.

It would be of interest to establish by way of a construction task like that described in Section 6 (paragraph 15) whether representations such as that in Figure 1a (this commentary) are perceived as 2D or 3D. As far as can be judged, the representation is entirely lacking in cues for depth. Is it genuinely seen as 3D? Figure 1b is rich in depth cues and can be expected to be seen, like the truncated pyramid, as 3D.

The second ground for criticism of the 2/3i–2/3d distinction is the notion of awareness of depth and solidity by "indirect" cues. Surely such awareness in the absence of depth cues should be regarded as an inferential cognitive process based on familiarity with the represented object. To make the distinction between perceived and inferred depth, the first derived from cues and the second from prior knowledge, is not to split hairs. The processes can legitimately be regarded as different. One is cued by features of the stimulus array and the other by stored information. In brief, I suggest that the distinction between 2/3d and 2/3i representations is that between the processes of perceiving and cognizing.

Deregowski's extensive review of picture perception in different cultures has led him to the view that a "fundamentally specialized skill" is involved. This skill has several components, the most basic of which is an ability to identify the circumstances in which other "picture skills" should be applied. Deregowski goes on to contend that these skills are necessary but not sufficient for the perception of depth in flat pictures. Depth perception can occur only if the 3D value of the impoverished cues can be recognized, an ability, it is claimed, that varies between populations. In short, it is argued that the recognition of cues – presumably cues such as linear perspective, overlay, elevation in the visual field, and aerial perspective – is a necessary prerequisite for the perception of depth itself.

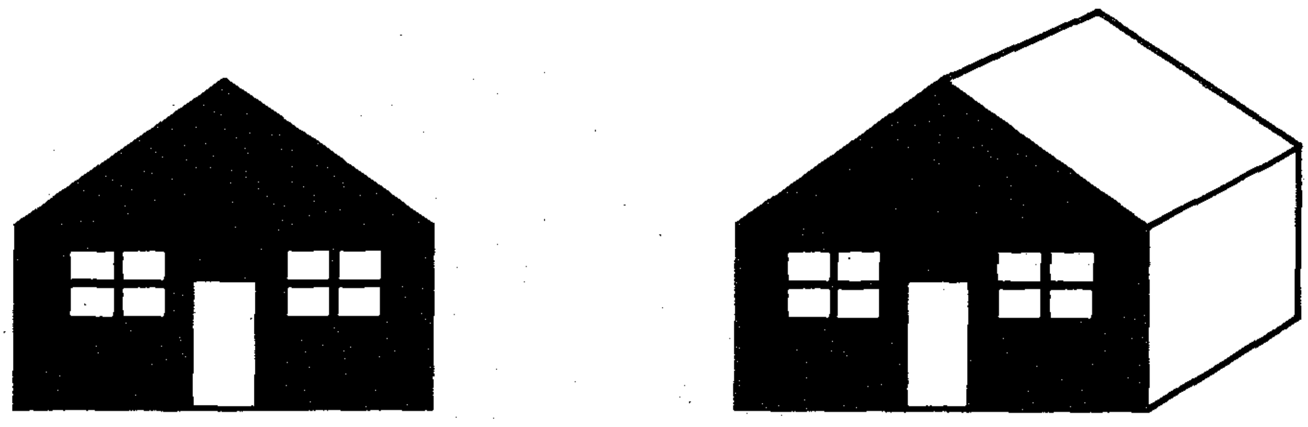

Figure 1 (Day). Alternative example of (a) a 2/3i image and (b) a 2/3d image.

I presume that Deregowski means what I (and the Shorter Oxford English Dictionary, 1973) mean by *recognize:* "To know by means of some distinctive feature; to identify from knowledge of appearance or character." If this *is* what is meant by recognition, Deregowski is contending that to perceive depth we must know our cues. Hence one may legitimately ask whether this notion is intended to encompass depth perception in, say, stereoscopic pictures in which the cue of retinal disparity is the primary determinant of perceived depth. If so – and it would be in the interests of parsimony to include this case – we should remind ourselves that compelling apparent depth occurs in random-dot stereograms (Julesz 1971) in which disparity cannot be recognized. One doubts that it is recognizable even in conventional stereograms, at least not without careful scrutiny. Depth is also apparent in shadowgraphs of rotating 3D objects, the kinetic depth effect or KDE (Braunstein 1976; Wallach & O'Connell 1953). It is greatly to be doubted that cues for depth, such as sinusoidal velocity functions (Braunstein & Anderson 1984) would be recognized prior to perceiving depth in this situation. Nevertheless, in the interests of parsimony and consistency it is reasonable to expect that the cue recognition claimed by Deregowski as a prerequisite for depth perception in pictures should obtain also for depth perception in stereograms in a stereoscope and in the KDE.

My summary comment on Deregowski's paper is that I would be far more prepared to accept his key concepts of 2/3d and 2/3i images and cue recognition as a basis for apparent depth in pictures if both had been validated independently of the data they are intended to account for. They are both interesting ideas but cry out for empirical support.

Representations of space and place: A developmental perspective

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In searching for answers to questions about the nature of real and represented space, Deregowski elects to look far afield, focusing on cross-cultural (and even cross-species) studies whose limitations are, as he admits, manifold. On the other hand, his basic strategy *is* illuminating, identifying fascinating phenomena and offering productive concepts.

Might not this illumination be brought closer to home, so to speak, by a rigorous and complementary exploration of developmental studies? Many of the phenomena that Deregowski identifies can also be seen in recent work on children's understanding of graphic representations of space and place (see, for example, DeLoache 1987; Liben & Downs, in press; Wolf & Gardner 1985). Moreover, many of these studies use a degree of experimental control that is sometimes difficult to achieve in cross-cultural research.

Take, for example, another case in which subjects have limited experience with pictures. Liben and Downs (in press) gave children, between the ages of 3 and 6 years, a series of place representations (road maps, aerial photographs, and so forth). Not only were their spontaneous comments captured but also their responses to increasingly specific probes such as: "What do you think this is?" "Could you find a(n). . . .?" "Do you think that this could be a(n). . .?"

Approaching this data from a Piagetian perspective, we were concerned with the "stand for" relationship between a representation and, in this instance, a place (or space). Successful understanding of *any* representation requires a simultaneous appreciation of the holistic "stand for" relationship (the representation as a whole standing for something else) *and* the componential "stand for" relationship (elements of the representation standing for elements of the referent).

Our findings from these and other data fit the picture that Deregowski develops. For example, the holistic "stand for" relationship (which, if not appreciated, leads to Deregowski's absence of picture perception) develops slowly and in complex ways. Children can understand the basic relationship, perhaps even as early as three years of age. They can distinguish between forms of place representation (e.g., maps versus pictures). They share a prototypical map concept with adults, although this map concept changes with age and, presumably with exposure and use, gradually encompassing a broader range of forms. As Deregowski argues, picture perception is *not* immediately available to young children, although this position is not uniformly held (see, for example, Landau's [1986] discussion of maps).

The componential "stand for" relationship is more complex, depending, as it does, on the interaction of three factors: context, iconicity, and convention. Context is essential in understanding maps because one must appreciate dimensional systematicity, thus maintaining size and scale relationships. Loss of context can be abrupt. On an aerial photograph, one child could find buildings, knew they were buildings, despite the fact that they were small, and yet claimed that a road could not be a road because it was "too narrow for two cars to fit on." Children failed to understand the separation between a symbol and its referent. Children believed that a road shown in red on a road map would actually be red if you stood on it in the real world. Components of the representations were interpreted on the basis of what they looked like and thus a baseball diamond on an aerial photograph was said to show "a guitar" and "an eye."

Young children struggle to understand the interaction between context, iconicity, and convention, and thus their interpretations of place representations are full of errors. These errors are readily interpretable from a Piagetian perspective. Confusions of scale, for example, may be attributed to a lack of understanding of proportionality and metrics. Reification of map symbols results from nominalism. What is important from the perspective of Deregowski's target article is that many of the phenomena he identifies in cross-cultural contexts can be identified in a developmental sequence, albeit within one culture. There is a parallelism in terms of basic phenomena.

Indeed, as representations, maps present an interesting case in terms of the kinds of spatial cues present in the image. Consider the case of topographic representation. Spot heights on maps are 2/3i. Hachuring and relief shading are 2/3d. Contour lines are difficult to classify, falling in between 2/3d and 2/3i, perhaps forming a 2/3h (hybrid) category. Wood (1977) explored topographic representation throughout the history of cartography and within the development of children, identifying three ordered sequences in relief depiction: a picture-to-abstraction shift; a profile-to-plan shift; and a generic-to-unique shift. These shifts stand for different representations of information in either 2/3d or 2/3i modes, historically and developmentally.

Of equal importance is the extent to which Deregowski's conceptual framework can be applied to making sense out of developmental data. His discussion of the nature of picture difficulties is particularly interesting in that it emphasizes the role of expectations in picture interpretation. On what basis do children accept maps (or any other place representation form) as a representation of the world? When and how do children understand that a pattern of lines and colors or gray tones stands for a place (Downs & Liben 1988)?

Two recent studies throw some light on this question. Wolf and Gardner (1985) showed how kindergarten and first- and second-grade children can "tune" their production of a graphic representation of a model town to the demands of either map-making or drawing. There are age-linked changes in the ability to differentiate between maps and drawings showing trends in comprehensiveness, detail, symbol labelling, accuracy, orientation, proportion, and drawing angle (see Perry & Wolf 1986). DeLoache (1987) presents a striking demonstration of the sudden achievement of the understanding of the symbolic relation between a scale model and the larger space that it represented. Three-year-old children could make the link between the two whereas 2½-year-old children could not. The link requires that the model (the representation) be thought of in two ways at the same time, as a thing in itself and as a symbol. Interestingly, the younger children could make the link in the case of a photograph of the space.

The logic that Deregowski outlines for a cross-cultural approach applies equally well to a developmental approach within a single culture. Certain phenomena are indeed more readily observable in some groups than others. The advantage of developmental groups lies in the possibility of a systematic approach to understanding the genesis of pictorial representation.

What you see isn't always what you know

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Jan Deregowski argues that the failure by members of nonpictorial societies to recognize a picture as a representation and their failure to recognize objects in pictures reflect two different types of skills: those related exclusively to either real or representational space, and those related to both. He builds his argument by examining the patchwork of cross-cultural research, and although he fails to define clearly such constructs as "real space," "skill," "spatial," or "represented space," he nonetheless makes some interesting distinctions in his target article, and offers a schematic representation of the possible relationship between spatial and representational skills.

In contrast to more recent information-processing or Piagetian perspectives, Deregowski appears to be arguing about real and representational space from an empiricist position. As I understand Berkeley (1709), we obtain our knowledge of the external physical world from direct but unrelated sensory impressions, from images or faint copies of previous impressions in memory, and from a combination of impressions and memory in associative thought. As Freedman (1968) more recently observed, spatially oriented behaviors have been studied by Carr (1935), Howard and Templeton (1966), and many other empiricists in terms of the so-called spatial senses: vision, audition, and touch. Typically, researchers from this tradition have studied the cues in each sense modality or the cues themselves separately. As Freedman (1968) noted: "In vision, we have monocular and binocular cues for depth perception: relative size, interposition, linear perspective, aerial perspective, motion parallax, accommodation, convergence, stereoscoptic vision; *and we have done a great many experiments focusing upon one or another of these cues*" (Freedman 1968, p. 1; my emphasis).

Deregowski's view appears to belong to this empiricist tradition, especially as his paper contains references to visual cues, perceptual attributes, spatial properties in different layouts, illusion-evoking stimuli, imagery based upon different types of cues, and the disembedding (perception of figure from ground) and recombination (the structuring of scattered elements) of cues and images in associative or representational thought. Unfortunately, Deregowski fails to make clear the assumptions and definitions that he uses from this intellectual heritage, fails to embed convincingly the scattered cross-cultural studies he refers to in the literature from this heritage (see emphasis above), fails to relate his speculations and research findings to other approaches to pictorial perception and drawing (e.g., Freeman & Cox 1985), and fails to define or to establish clear boundaries between real and represented space, between representational and spatial skills, between figural and pictorial perception, and between image and illusion. As a consequence, his argument for two different types of pictorial skills has a superficial, meandering quality, and his schematic representation of the possible relationship between representational and spatial skills is unconvincing.

Central to Deregowski's paper is the idea that failure to recognize a picture as a representation and failure to recognize objects in pictures reflect two different types of skills. The difficulty with describing the problem in this way is that it is unclear what role recognition plays in either perception or representation. It is possible to argue, for example, that whereas one may recognize (perceive) objects before one recognizes (represents) pictures developmentally, one may also recognize (represent) what one recognizes (perceives) in pictures as an adult. Possibly recognition is itself a separate skill.

The difficulty is compounded by the fact that Deregowski is also inconsistent with respect to the meanings he gives to the term "representation." As Hans Furth (1968) pointed out, the term "representation" has different meanings depending on whether it is used in an active or a passive sense. In the active sense, "representation" means *"to make something present by means of"* (*rem praesentum facere*), with the person being the subject of the activity and a mediating instrument implied. Presumably, representation in the active sense is involved when we construct a model from a picture, draw a picture from a model, or perceive a picture as an object.

By contrast, Furth also noted that there are two variations of the passive sense of the term "representation." In the narrow variation, *"a map represents the outlay of a city,"* there is an inherent correspondence between the map and the city. In the broader variation, *"let X stand for all children in Washington, D.C.,"* *X* has no intrinsic relation to children, and knowledge of *X* by itself provides no information. Presumably, representation in the narrow passive sense is involved when we recognize objects in pictures and, in the broader passive sense when we recognize the illusion of three-dimensionality in a two-dimensional figure.

Deregowski's various uses of the term "representation" in his paper do not make it easier to follow his argument, especially when he attempts to distinguish between real and represented space. In the absence of a stated definition, it becomes evident from rereading the paper that Deregowski means by "real" space any orientation or layout of objects that is *outside* the observer, whereas "represented" space refers to how the orientation or layout of objects in figural or pictorial form affects what happens *inside* the observer. As Ittelson (1973) pointed out, however, whereas this distinction may serve well for object-focused space, it is not useful for surround or large-scale space. It is not clear, for example, how Deregowski would describe the behaviors involved when we estimate when to merge our car into high-speed traffic, when we predict how a room will look when the furniture has been rearranged, or when we attempt to retrace a route backwards through an unfamiliar city. Although all of these behaviors have a "spatial" character (Eliot 1987), it is unclear the extent to which they entail either "real" or "represented" space, or a combination of both at any one time. It is also unclear whether Deregowski's "orientation and layout" characterization of space is sufficient to encompass the entire range of possible spatial behaviors.

Despite the lack of definition and the inconsistencies in this paper, Deregowski is to be commended for making some important distinctions, and for reminding us how little we know of cross-cultural differences in spatial perception and representation. His speculation about the relationship between figural disembedding and synthesis tasks, for example, deserves careful thought, although perhaps without the encumbrance of his descriptive terms "archaic" and "totalitarian." Moreover, his distinction between 2/3i and 2/3d is an interesting one that cries out for further elaboration. His distinction between representational and spatial skills is unconvincing in light of richer and more informative distinctions from information-processing and Piagetian approaches.

Deregowski's review of cross-cultural research contains an important updating of Hudson's (1960; 1967) and of Segall et al.'s (1966) work on the pictorial perception by members of nonpictorial societies; it reminds us of the range of Deregowski's own research and the considerable contribution he has made to our understanding of differences in cross-cultural perception and representation, and it underscores the urgency of studying cross-cultural differences before they are overcome by increasing technological sameness in a rapidly shrinking world.

The distinction between object recognition and picture recognition

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Deregowski's target article contains many valuable points concerning the representation of spatial information. I shall confine my comments to two of the issues he raises: (i) the parallels between the inability of some primitive peoples to perceive pictures and the breakdown in agnosic patients of the recognition of complex objects; and (ii) the distinction between real objects and their pictorial representation. These are closely related topics and each is significant to our eventual understanding of visual recognition processes.

The failure by the Me'en in remote Ethiopia to perceive pictures of animals is noteworthy. Typically, Deregowski et al. (1972) found that Me'en subjects picked out parts of the picture and made guesses based on incomplete information. There often seemed to be a problem in integrating individual features to form a gestalt. For example, when shown the dik-dik one woman was able to identify individual parts quite well saying "Those are legs, horns, tail" and then adding "I don't know what it is." In other instances hypotheses were generated but were wrong (though from related categories), for example, a man shown the same picture responded "It has horns, leg . . . . front and back, tail, eyes. Is it a goat? A sheep? Is it a goat?" This type of category error is different both from failure to integrate and from the kind of total misclassification made, for example, by the man shown a picture similar to Figure 18a (reversed). He perceived the man to be an aeroplane and construed features such as his legs as being the plane's wings. But gradually, as the experimenter outlined the head, the subject's hypothesis changed to believing that it was a picture of a man rather than an aeroplane and that the "wings" were indeed legs.

How do these responses compare with those made by agnosic patients? Lissauer (1890) first drew attention to agnosia: He described a patient Gottleib, L. who, following a cerebral accident, was unable to identify common objects. He also complained that his vision was blurred and that he saw everything as though through a fog. According to Lissauer, the patient had lost the symbolic meaning of visual impressions. This produced responses from Gottlieb, L. that, superficially at least, are similar to some of those elicited from Me'en subjects by Deregowski et al. (1972). Shown a fountain pen he volunteered "That's a light" and only changed his hypothesis after touching it. A handkerchief was perceived as "spectacles" and a door knob successively as "snuffers," "candlestick" and "key." It is important to note, however, that agnosic patients may display difficulties with objects as well as pictures of objects. Humphreys and Riddoch (1987), in their report on the agnosic patient John, describe his difficulties in identifying both real objects and representations of them in photographs and line drawings. John performs better with real objects; Humphreys and Riddoch speculate that this is the result of their providing more information. The point I wish to make here, however, is that people such as the Me'en do not seem to have difficulties in identifying real objects; only represented objects pose problems.

Models of object recognition tend to take the form suggested by A. Ellis and Young (1988), shown in Figure 1 (this commentary). Notice that at the input stage they make no allowance for a distinction between visual information from real objects and depicted objects. Yet evidence such as that provided by Deregowski clearly suggests that there may be good grounds for supposing that the two routes to recognition are not identical. There are also good philosophical reasons for distinguishing these (see Schier 1986), and Deregowski has reminded us that there are equally cogent psychological arguments for doing so.

It so happens that at least one model, one aimed specifically at explaining face recognition, does make a distinction between real and represented objects. Bruce and Young's (1986) theory of face recognition allows for the possibility that photographs and real faces may not be processed identically at the early stages of recognition. According to their conception, a photograph gives rise to a pictorial code that is distinct from any view-specific information (see Marr 1982): It represents a static visual event and "is probably of little importance in everyday life."

Figure 2 (this commentary) gives an indication of one possible

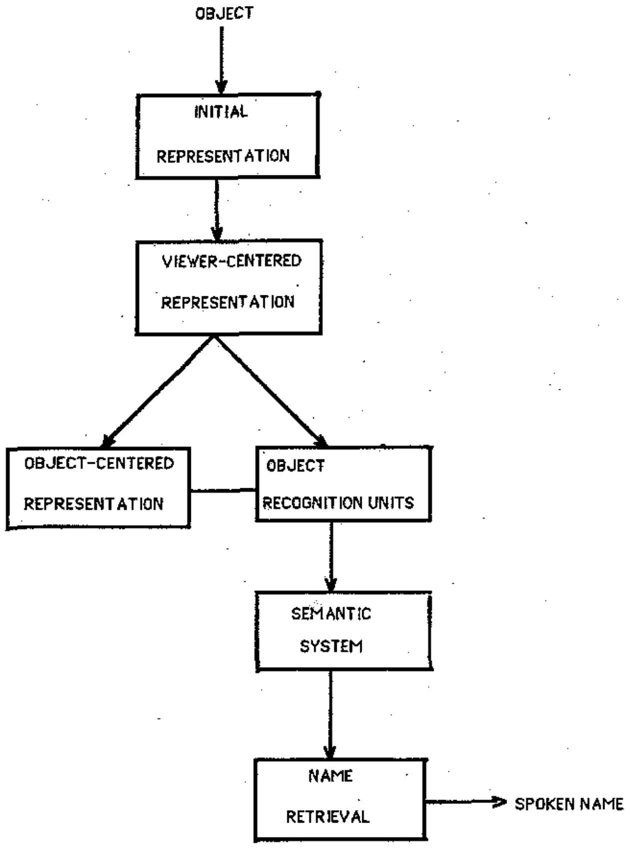

Figure 1 (Ellis). Model of object recognition (adapted from A. Ellis & Young 1988).

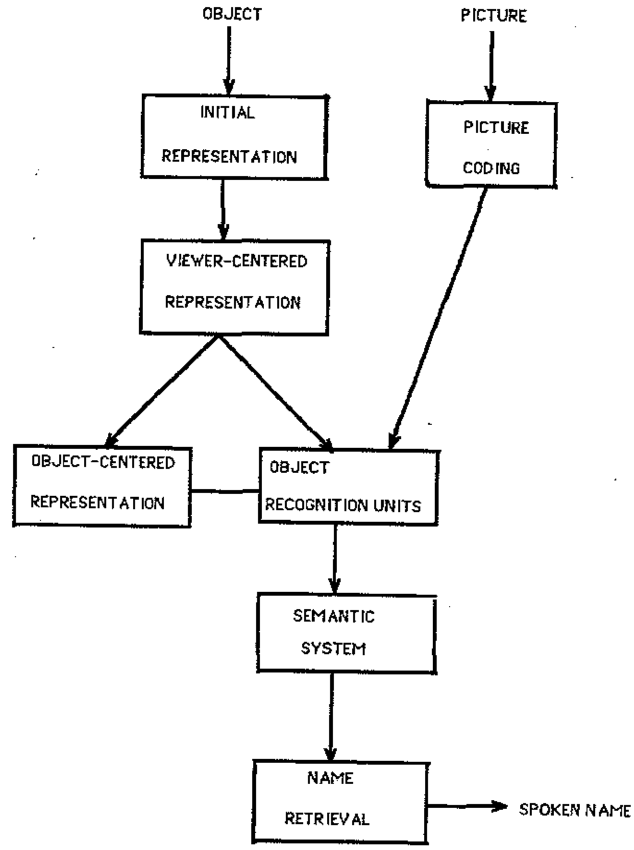

Figure 2 (Ellis). Model of object and picture recognition suggesting that, initially at least, the two processes are distinct.

interpretation of Bruce and Young's (1986) model applied more generally to object recognition. Using this to reexamine the data derived from primitive people and agnosics, I shall attempt to reconcile the various observations and to show how the two populations, though displaying superficially similar visual recognition difficulties, may do so for markedly different reasons.

If we accept Bruce and Young's (1986) postulation of a pictorial code it is necessary to assume that this process is learned, probably through contact with pictorial material. The only evidence against this hypothesis is the observation by Hochberg and Brooks (1962) of a child brought up without access to pictures until the age of 19 months who nevertheless seemed able to identify objects in pictures. The authors admitted that they could not avoid allowing the child to encounter billboards, picture books, and even TV. It is also likely that the child saw pictures on vehicles and many other sources of public information, however diligently his caretakers tried to prevent him from doing so. Consequently, I am willing to ignore Hochberg and Brooks's claims, in favour of accepting the findings of Deregowski et al. (1972) that people who have had absolutely no access to pictorial experience do not easily recognize pictorial representations of objects. The evidence seems to suggest that pictorial recognition requires a period of learning to become established.

Agnosic patients were subdivided by Lissauer (1890) into two types: apperceptive and associative. It is the former patients who produce errors similar to those elicited from Me'en subjects; but, because they have difficulties with both real and depicted objects (albeit greater difficulties, perhaps, with the latter) it is parsimonious to assume that these difficulties arise from damage to a later stage, common to input from real objects and pictures. The stage labelled ORU in Figure 2 is the most likely candidate. For associative agnosics, who perceive normally but cannot match the percept to stored information, the likely explanation is that there is a disconnection between the ORU stage and the semantic system. Of course, this theoretical analysis by no means exhausts all possible explanations even within the confines of the information-processing model shown in Figure 2. Moreover, the possibility that pictures and real objects are processed by distinctly different modular systems should not be overlooked.

Deregowski's paper serves *inter alia* to remind researchers that picture and object recognition are not identical processes: Most of us are at times guilty of failing to make this distinction, and consequently we produce oversimple models of the recognition process. The use of cross-cultural data by Deregowski and others can be considered to be not only useful but essential to our eventual full understanding of recognition processes.

A computational approach to picture production and consumption is needed right here

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A unified competence-theory of relations between environmental space and representational space is not yet available. Both Gibson and Marr left the task unfinished at crucial points (Costall 1985; Willats 1987). Such a theory would have to specify how the generation of mental descriptions interfaces with constraints in the cultural canon that specify aspects of pictorial authority. Even in the richest hunting ground, the terrain of Western iconomanes (as Schier, 1986, rightly calls us), *we do not know what generates iconophilia or what integrates the production, distribution, and consumption/utilisation of iconic repre-*

sentations. This makes forays into remote populations a hazardous affair, for, lacking a proper theory of how pictures work, it becomes difficult to interpret cases of failure to work. This is in part because we lack a specification of what the most authoritative depictions should be like. Thus, what principles dictate the use of oblique projection which appears in the target article from Section 6 (paragraph 11) onwards? I shall shortly argue that this is a difficult projection system to classify. But first consider what unity the reviewed phenomena may have.

Unity of the evidence. Liben and Downs (1986) found that children suffer iconic intrusions when given maps of environmental space – after identifying two roads, they might identify the region where the roads meet as a small piece of cheese! Freeing oneself from the compulsion of an "iconic base" is probably not reliably achieved until age nine or ten. An iconic base is a mental resource which enables people to act as icon-detectors. It contains a set of criteria for detecting when stored knowledge of referents has been directly accessed by a stimulus which is perceptibly not a token of the type of referent recognized (but is nonarbitrarily similar to real tokens). In what sense is an iconic base unavailable to "remote populations" even under optimal pictorial conditions?

The first problem is that phenomena such as mistaking a representation of a tortoise for a snake might well attest to the *power* of an iconic base – an intrusion triggered by a sudden recognition – or it could be a fallback interpretation after failure to integrate the iconic assemblage. That would need a dedicated investigation using converging operations rather than an appeal to even less well integrated representations such as Figure 15.

The second problem is that illusory figures do not provide reliable circumstantial evidence for pictorial processing. Despite Deregowski's exemplary caution about elevation and depth components, "perception of certain illusions such as the Ponzo . . . involves the immediate transfer of 3D spatial skills into the realm of pictures." But if you lay a Ponzo on its side and draw round it so that the converging lines become the gums of a gaping crocodile in profile (add teeth if desired according to your cultural canon) the illusion occurs without elevation or explicit depth. The target article would classify your picture as "2/3i"; to be firmly separated from an explicit approximation to linear perspective. Lack of a process-model for such illusions prevents them from being evidence for the availability of an iconic base.

Turning to the studies reviewed, not all of them were designed to distinguish between availability and accessibility of an iconic base. The distinction between knowing what procedure to implement, how to implement it, and when to implement it is investigable (Bryant 1985); and many computational skills that do not appear in institutional settings surface in the population's vernacular (e.g., Carraher et al. 1985). Optimal tests should be packaged to make "human sense" in the subject's own terms (Donaldson 1978). And, if a test demands a judgment, subjects should be given access to materials sustaining a contrary judgment: The power of *simultaneous contrast* in depth-related pictorial skill was independently discovered by Cox (1985), Davis (1985), and Light (1985), and it surely applies to the model-building tasks under review.

In sum, one wonders how accessible an iconic base would be to pictorially deprived collaborators in a joint enterprise. Research practices would be different from those with which the target article had perforce to deal.

In the absence of a competence account, what would a functional theory of pictorial representation specify as primary evidence? To the best of my knowledge there are only two detailed ones on offer. One is from Bryson (1983), who argues that it is a category error to treat a representation as a record of an environmental perception, by conflating structure with

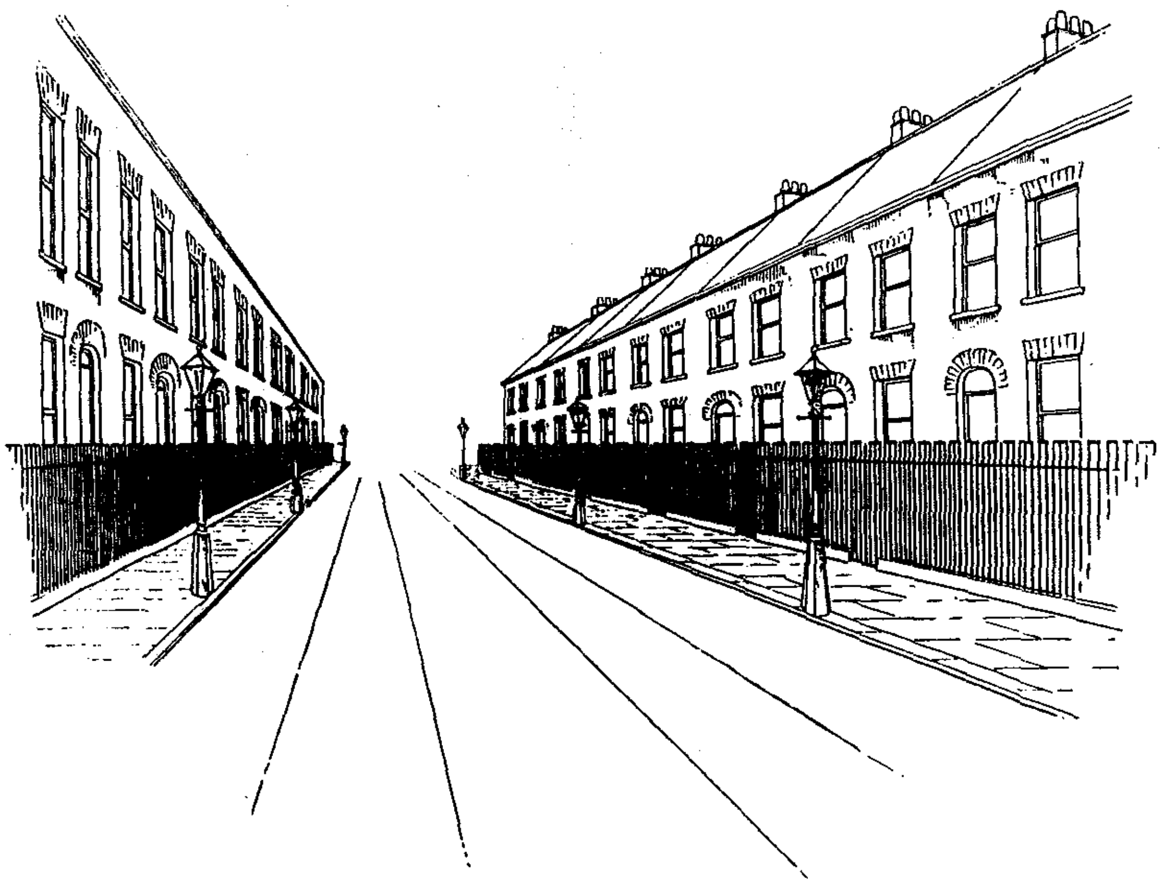

Figure 1 (Freeman). Frontispiece from Armstrong's (1893) edition of Cusack's tutorial handbook showing that orthogonals at eye-level form an exception to the rule that all orthogonals in perspective should be drawn as obliques.

transmittable information. He argues that only a theory of signs can deliver an account, and he applies one at all levels, from picture primitives such as curves to composition. Such an approach would encompass the setting of goals for representations (as in Goodnow et al. 1986; Wilson & Wilson 1982; 1984) as well as the semiotic vernacular (Harrison 1987).

The second piece of primary evidence for a functional theory of pictorial representation is from Schier (1986), who argues as an issue of principle that only evidence *subsequent* to an initial pictorial interpretation is relevant to populations' access to iconic modes – what he terms "natural generativity" (p. 43). That means setting aside the first pages of the target article, and the Hudson test, and regarding Section 6 (paragraph 11) as the point of departure for a functional cross-cultural account. That seems draconian, but it is, after all, the prime purpose of any functional model to concentrate forces.

Computational considerations. The target article presents an account of space and asserts: "The notion of skills used above is, of necessity, global." I think that that "of necessity" is plain wrong: "Perception is the construction of a description . . . that's the core of the thing" (Marr 1982, p. 345); the process of construction can be analysed into its component primitives, transformation rules, and coordinate assignments. Normally, the system generates descriptions organised around the principal axes of the object; but under very abnormal conditions, Schier's "recognitional acts" can be carried out from viewpoint-centred descriptions (Humphreys & Riddoch 1984; Riddoch & Humphreys 1986).

Let us apply the approach to a cube in oblique projection. What description does the viewer build? Certainly space becomes structured around the representation (Hagino 1976) but is this done by depth-assignment to surfaces or is it the product of volumetric computation? Arguments for the latter occur in varying forms in Duthie (1985), Freeman (1986; 1987) and Willats (1987) – the obliques may be viewed as a solution to the local problem of joining adjacent regions. Thus, Scottish adolescents had severe problems in copying surface markings on the cube's oblique face, which they presumably would not encounter if these either specified that face as a surface-primitive or accessed a viewpoint-centred description. In that light, I found Deregowski and Strang's (1986) ingenious surface-ablation method to hold more promise of future analytic cross-cultural insight than the majority of the studies reviewed in the target article. But then the centre of interest would shift to the Orient rather than Africa, for culturally canonical reasons.

Now consider converging perspective lines, as in Figure 1. The dotted tops of the railings may seem to slope downwards a bit, despite their potential anisotropic-privileged status. Freeman, Evans, and Willats (Freeman 1988) found that English undergraduates sloped them by a mean of 32° ± 15° when trying to copy the figure (but only by 7° when using the old forger's trick of inverting the figure to aid a viewpoint-dependent description). The figure exerts its depth effect by relying on the psychological difference between an axial horizontal at an early stage of computation and a nontilted oblique at a later stage, despite the geometrical coincidence. I was disappointed that cross-cultural researchers eschewed pictorially rich projections and considered the deliberately meagre and idiosyncratic Hudson materials (see Miller 1973).

Conclusion. There is much of interest in the target article, and many points at which the above arguments coincide with its material. But overall I cannot endorse the conclusion that "the findings call for theoretical explanation." They form too shifting a pattern. Their role is, I suggest, to expose some assumptions, weaknesses, complexities, and unmet challenges in any competence theory of depiction. That is where theoretical work should be directed, whence new paradigms will surely be compelled for challenging ethnocentrism, and yielding the cross-cultural findings on the accessibility and availability of the iconic base to be theorised.

Things and pictures of things: Are perceptual processes invariant across cultures?

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Deregowski has provided an excellent review of cross-cultural research in space and picture perception. The issues addressed in this target article are, in their more general form, a variation of the centuries-old nature/nurture question: To what extent does experience affect perceptual processes? In answering this question, Deregowski examines seven different types of perceptual skills. They are the perception of:

1. real-world objects;
2. spatial relationships among real-world objects;
3. pictures of objects;
4. spatial relationships among represented objects;
5. objects in photos;
6. diagrams; and
7. the interrelationship among these distinct perceptual tasks.

Because of the tremendous diversity among these tasks, it is reasonable to expect that the effect of cultural experience will differ depending on the nature of each.

It is always difficult to answer nature/nurture questions. Experimental results depend on a large number of variables including: *subject variables* such as the types of experiences subjects have (e.g., carpentered worlds, limited experience with distant objects because of surrounding mountains or forest, exposure to pictorial representations), age, intelligence, education, and language; *display variables* such as viewing conditions, type and number of cues to depth in a picture, photo color and clarity, and familiarity of objects and their context; and, *response variables* such as whether the response involves reproducing an object with three-dimensional materials or on paper, naming the objects, reproducing judgments of distance, or recognizing an object or distance relationship.

Given Deregowski's excellent review of the literature in which he explicated the shortcomings of much of the research in this area, I was surprised with his conclusion that "different cultural groups use different skills to perform the same perceptual tasks." There is very little evidence that perceptual processes vary as a function of culture. Let's consider some possible manifestations of culture-related differences in perception.

Confusing real-world objects with their pictorial representations. There is no sound empirical support for cultural differences involving confusions of objects and pictorial representations. Even the interesting story about the surprise response in 1904 by Ugandan natives when they were confronted with a large projection of an elephant does not permit the interpretation that they believed the projection to be a live animal. The chief's willingness to investigate the image is not indicative of such a confusion. On the other hand, people from pictorially sophisticated societies are sometimes fooled by trompe l'oeil pictures. A conservative conclusion is that there are two-dimensional representations that do not fool most people of any culture, and there are other two-dimensional representations that fool most people in all cultures. In order to claim that cultural differences exist, a systematic investigation of critical display variables that would yield differential cultural responses is needed. Experimental paradigms of this sort would allow us to identify which aspects of a display or which viewing conditions are responsible for the response differences among cultures.

Inability to perceive objects or depth in two-dimensional representations. There are very few reports of cultural groups who were unable to perceive objects depicted in photos or drawings. As Deregowski noted, "the frequency of that is probably so low that the effect is of little consequence." Hudson's (1960; 1962; 1967) seminal and oft-cited studies demonstrating cross-cultural differences in pictorial depth perception have been criticized for several reasons, as delineated in Deregowski's astute critique. Cross-cultural studies that have measured the strength of illusions as one approach to studying this problem, have also failed to provide strong support for cultural influences on perceptual processes. While some illusions are reduced in magnitude among people with little experience in carpentered worlds, the illusory effect is still similar in kind to that experienced by Westerners (e.g., Pederson & Wheeler 1983). Given that there are often large individual differences in the magnitude of illusions within a culture, these results do not support the notion of cultural differences in the underlying perceptual processes. Other studies of the inability to use real-world depth cues are either anecdotal, lack an appropriate control group, or are methodologically flawed in other serious ways. (See Coren & Girgus 1978, for a review of the literature pertaining to visual illusions.)

Diagrams and the manipulation of other abstract representations. Deregowski's final reason for studying cross-cultural perception is pragmatic: "Students of engineering may, in some cultures, find great difficulties in comprehending represented space." For Deregowski, represented space includes photos, line drawings, drawings with varying types of three-dimensional cues, and diagrams. The ability to utilize the information in diagrams is conceptually different from the perceptual skills needed in the other examples of represented space because of the arbitrary and abstract nature of the representational symbols used in diagrams. For this reason, the interpretation of diagrams is more closely related to reading than it is to picture perception. Translating the blueprints of a house into an image of the house, for example, involves processes that are more cognitive in nature than those involved in perceiving the properties of a house from a drawing or picture.

The efficient use of arbitrary symbols is a learned skill that differs in many respects from object and picture perception. Several studies have shown that when children and adults receive spatial-skill training they improve on embedded-figures tests and other paper and pencil tests of abstract visual-spatial ability (see Halpern 1986 for a review of the literature). Deregowski's report that "students from some cultures may find it particularly difficult to understand diagrams" is no more surprising than reporting that students from some cultures are better readers of English.

In conclusion, Deregowski's own literature review does not support his conclusion that different cultural groups use different skills in performing the same perceptual tasks. Empirical data in favor of the cultural-differences hypothesis tend to be weak and subject to alternative explanations. In the absence of convincing evidence of differences, the customary practice is to retain the null hypothesis. A more likely conclusion is that while the efficient use of abstract visual-spatial symbols depends on cultural factors like education and experience, the processes involved in real-world and picture perception are invariant across cultures.

The representation of space: In the 2/3i of the beholder

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By its very nature, there is a problem of choosing a scope and focus when conducting research. Coombs (1983) discussed this as the problem of generality and power of a theory. He argued that any set of theories that trade off generality for power, or vice versa, are incomparable. In contrast, any theory that yields more power or generality without the loss of the other is to be preferred. Deregowski makes a conscious effort to broaden the domain of focus, and thus the pool of experimental data, by reporting cross-cultural studies in picture perception. Unfortunately, he has also made a conscious effort to ignore many other issues and in doing so he paints a limited model of the representation of space for pictures.

One distinction Deregowski makes throughout the target article is between 2/3i and 2/3d images, or, as he concedes later, cues in images. By focusing on the 2/3i versus 2/3d distinction, Deregowski misses several other important issues concerning picture perception. For example, Deregowski sidesteps interesting developmental data showing that infants as young as two months prefer pictures of faces over pictures of other objects or patterns (Maurer & Salapatek 1976). Even if this is due to a preferred status of faces in recognition (as suggested in Deregowski's note 6), at minimum, these data suggest that there is an immediate recognition of some features that are clearly not related to depth cues, yet would provide depth information through the process of recognition. The ability to detect such features would be neither a representational skill, such as interpreting a stick figure as a human, nor a 3D spatial skill, such as estimating distances in a field, yet feature detection would be critical to the interpretation of a picture and for generating depth cues.

Current theories of picture and scene recognition (e.g., Feldman 1985) suggest that bottom-up cues, such as features and texture gradients, are combined with top-down context links provided by schemata and expectations. In terms of picture processing, depth cues can be provided simply by a context, which can in turn result in improved memory for pictures (e.g., Mandler & Parker 1976) and improved object recognition within pictures (Biederman et al. 1982). The presence of such schemata is strong enough that it can result in distortions such as seen in the hierarchical clustering of locations (Stevens & Coupe 1978). The role of a schema is to provide top-down processing constraints on the recognition process. By such theories, represented space is constructed through feature recognition, depth cues, and schema induction. To limit the set of skills needed for depth perception to 3D spatial skills and representational skills is to paint a limited picture of a complex operation. [See also Arbib: "Levels of Modeling of Mechanisms of Visually Guided Behavior" *BBS* 10(3) 1987.]

At the same time, I agree with Deregowski that cross-cultural studies will illuminate differences that may be hard to observe within one culture. Hutchins's (1983) work on the mental models used by Micronesian navigators suggests unique computational solutions to complex problems and Kearins's (1981) work on the spatial memory of Australian Aboriginal children, in addition to the work presented in the target article, clearly shows the benefit of cross-cultural studies. However, it is equally important not to ignore research that can complement cross-cultural research to build a complete model of how spatial relationships are derived from pictures.

Different skills or different knowledge?

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Deregowski claims that picture recognition involves both the identification of the pictured object *and* the portrayal of the pictured object. Although allowance is made for some overlap of skills, different sets of skills are postulated for these actions: One set (3D skills) is used in the perception of real objects and another set (representational skills) is used in the perception of pictures (see Figure 25). However, it is possible that the same mechanisms or skills that process real-world scenes also process represented scenes; such processing need not involve any distinction between real and represented space. Rather than treating real space as "space" and representational (pictorial) space as "object," both the real and the representational space may be just plain "space."

Deregowski claims that perceptual skills acquired in real space are not as useful in dealing with pictures that indirectly portray space (2/3i) as they are with pictures that directly portray space (2/3d). This may be true, but for reasons different from the ones the author proposes. Deregowski considers these two types of pictures as distinct categories; instead, they may fall along a continuous scale where 2/3i and real space (3D) occupy the ends of the continuum, and 2/3d space is somewhere in between. At the 3D position, all perceptual skills are relevant, but as a stimulus approaches 2/3i, certain cues become less relevant or even absent. Thus, skills appropriate for 3D may not be useful for 2/3d or 2/3i. This is not, however, to suggest that different perceptual skills must apply to the different forms of representation; rather, different skills may be more effective at different levels of real and represented space.

Our recent work (Hubbard & Baird 1988; Hubbard et al., in press), as well as work in mental psychophysics (Hubbard 1988; Moyer et al. 1978), suggests that skills useful in dealing with real space are also useful in dealing with a form of representational space, specifically, visual images. In this case, the same skills applied to external real space can be applied to internal representational space. Furthermore, if images are metaphorically considered as "pictures in the head," then the skills useful in dealing with internal representations should be equally useful in dealing with external representations. Some of these skills include perception of size and distance, the two variables needed to specify a visual angle.

Objects are typically remembered or imaged at "familiar distances," (Hubbard et al., in press) with larger objects generally remembered at greater distances than smaller objects. For example, an elephant is remembered or imaged at a greater distance than a mouse. A familiar object at a familiar distance thus subtends a familiar visual angle. If recognition of an object involves matching the visual angle of the object-in-the-world with the visual angles of objects-in-memory, then a failure to find an appropriate match results in the stimulus being unidentified or misidentified.

A striking example of the importance of visual angle is reported by the anthropologist Turnbull (1962). Kenge, a native of the Ituri Forest of Africa, had lived his entire life in the dense tropical rain forest. Upon leaving the forest for the first time and gazing out on a distant herd of buffalo on the wide-open grasslands he asked: "What insects are those?" Because the herd was a considerable distance away, the visual angle subtended by each buffalo was very small. This small angle would be similar to that subtended by insects at the much nearer distances within the rain forests of Kenge's experience. Because Kenge was not familiar with objects at these extraordinary distances, he interpreted the large, distant animals as tiny, nearby insects.

By similar logic, a person's face may typically subtend a particular visual angle whereas that same person's face in a photograph subtends quite a different visual angle. The pattern of the face in a photograph is not recognized as a face because it is seen at a visual angle quite different from that at which it is ordinarily perceived. In order for a real face to subtend as small a visual angle as in a photograph, the person would have to be very far away, yet the photograph is held in the hand. The face is the wrong size for the distance! If the difference in visual angles underlies the failure to recognize the person portrayed in the picture, then recognition should be markedly improved if the picture is made life-size. In this case, the visual angle subtended by the portrayed face would be identical to that of a real face at the appropriate distance. Deregowski's example of a primate perceiving a photograph of a spider to be a real spider is thus perfectly explainable *if* that photograph showed the spider at the correct visual angle at which a real spider is normally perceived.

Deregowski claims that pictures should be treated as objects, but it is more parsimonious to assume that pictures are *not* treated as objects. In the latter framework, similar processing mechanisms are utilized by real and representational space. The stimulus, be it real space, picture, or image, can be accessed and processed by the same basic mechanisms. The same types of cues are processed, regardless of whether they are derived from a picture or real space; the same types of mechanisms apply to the stimulus regardless of the nature of that stimulus. If parameters of the stimulus (such as color, visual angle, size, distance) match those in memory, then the stimulus is correctly identified.

A similar idea has been mentioned by Kosslyn (1980; 1981) in his description of an underlying buffer that is used by both imagery and perception. A similarity between the ways real and representational space are processed has also been touched upon by Finke and Shepard (1986; see also Finke 1980) and Shepard and Podgorny (1978), who argue that cognitive processes, such as imagery, may utilize mechanisms or processes similar to those used in perception. The finding of Brislin and Keating (1976) that subjects prone to the Ponzo illusion in pictures are also prone to the same illusion in real 3D space is consistent with this view.

Is the difference in skills postulated by Deregowski a difference in *perception* or merely a difference in *knowledge*? When the material on which a figure was printed was new and strange to the Me'en, they attended to the material and not to the figure. When the same figure was printed on a more familiar material, the Me'en attended to the figure rather than the material (Deregowski et al. 1972). This suggests that familiarity with the medium, rather than pictorial skills per se, is important. In a related study, Sigel (1968) reported that children found it more difficult to respond to pictures than to objects in a sorting task, suggesting that the perception of pictures is less a cultural skill than a maturational or learning skill.

Deregowski claims that failing to perceive a picture is symptomatic of defective picture perception. However, that is like saying that an inability to read an Egyptian hieroglyph is symptomatic of defective perception in the average American or European. Rather than being symptomatic of a defect in picture perception, such an inability may merely indicate a defect in (or lack of) knowledge of how to interpret the content of the perception. An observer whose skills don't overlap with those of the creator of the picture may find a picture incomprehensible, but again, this need not result from differences in perception; rather, a difference in familiarity with the materials seems more likely. The same picture may be seen as 2D, 2/3i, 2/3d, or 3D or a meaningless blotch, depending on the knowledge the perceiver possesses. The fact that the Me'en sniffed the photographs does not demonstrate that they have no skills for dealing with representational space. Instead, it may only show that they were not familiar with a photograph as a means of representation.

In the studies carried out by Dr. Laws, the pictures were in black and white. It is likely, however, that an object's color functions as a relevant dimension of the natural environment. It might be argued that the information the natives needed in order to detect the presence of the named objects was missing from the black and white pictures. That they eventually succeeded in recognizing the figures suggests that picture recognition is easily learned; the problems initially experienced were overcome with minimal instruction. As a result of instruction, the natives gained familiarity with photographs as representations and were then able to parse the relevent aspects and "see" the objects. The eventual perception of the pictured object by the natives is reminiscent of the perception of Street or embedded figures by subjects from pictorially sophisticated cultures; often a bit of coaching is required before the object is perceived.

Finally, the claim that pictures may not provide infallible means of cross-cultural communication is certainly true, but for reasons other than those given by Deregowski. Pictures may not be an effective means of cross-cultural communication because members of other cultures may not attend to the meaningful aspects of the representation. Like the Me'en, they attend more to the medium than to the message. This need not result from any defects of perception per se, only from a lack of knowledge concerning the relevant aspects of the representation.

Picture in visual space and recognition of similarity

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Deregowski's target article explores a field entirely new to this commentator, a psychophysicist interested in the mathematical analysis of the global structure of visual space and of color systems. The section devoted to the survey of the literature reminds me of when I studied clinical reports on space and shape in congenitally blind patients, before and after they underwent an eye operation (e.g., Sendon 1960). There were a number of puzzling and contradictory observations. The general tone of the target article is in the psychometric tradition based on data from testing, and hence Deregowski emphasizes the involvement of *perceptual skills.* Let me take the viewpoint of psychophysics.

Visual space is the endproduct of a long series of processes, rays from physical stimuli, physiological processes from the retina, and cognitive processes. Under ordinary conditions visual space is spanned according to the following structure. It is finite, compact, continuous, and three-dimensional. At the end of each line of sight there is always a percept, and all percepts are localized at a finite distance in front of the perceived self. A picture, if there is one, is a part of this visual space, and it has a pattern in it. I assume that the structure of visual space up to this point is the same for all human beings having sight. Problems discussed in Deregowski's article are concerned with what a pattern in visual space (what is called "real space") is recognized as corresponding to in a particular pattern in a picture (what is called "represented space"). The author refers to perceptual skills that may be obtained through learning of the "all-or-none" variety. Whether or not it should be called "skill," the real question is by what psychophysical process the given pattern of the endproduct is generated. In Figure 17, the same set of lines is viewed by all persons. Nevertheless, some see a 2D pattern, some a 3D pattern with the left square in front, and others the reversed 3D pattern. Which pattern is predominant may be cultural dependent. Yet this is not necessarily analogous to another culturally governed phenomenon: color terminology.

Color scientists assume that all people with normal color vision have the same internal processes: the same three kinds of cones in the retina and the same representation of color stimuli in a spatial form (color space). However, different cultures divide color space in different ways: For example, the most primitive tribes have only three names (white, black, and red) (see Berlin & Kay 1969). Color space as the endproduct of the psychophysical processes is the same; what matters is how to divide it. This can be learned, and Eskimos and Maoris have wide vocabularies for subtle nuances of white and red, respectively. On the other hand, perceiving the three different patterns in Deregowski's Figure 17 involves differences in the endproduct; hence there must be some condition in the psychophysical series itself which can lead to different endproducts. At present, we have no idea what that condition might be, whereas we do have some insights about the difference between the two processes generating reddish colors and greenish colors. I hope that field studies like those summarized in this article will be conducted to shed light on this psychophysical question.

To recognize a figure in a picture, whether the picture is 2D or 3D, one must do more than pick up the figure. Suppose there is a figure of a man in the picture. The percept of a man changes its size according to distance in visual space; to recognize the identity between these figures is a biological necessity for all living creatures. This skill involves the recognition of congruence in the context of distance. However, recognizing a man in a picture calls for one more step. In a picture directly in front of us in visual space, the figure is much smaller than a man standing at the same position. It is a necessary condition for understanding pictures that we recognize a *similarity* that is freed from the context of distance. In cognition as well as in mathematics, similarity (which means identity in shape only) is more than congruence (which means an exact match in size and shape). Mathematically speaking, congruence is definable in any Riemannian space of constant curvature. The only space in which similarity is defined between two figures at any position is Euclidean space. Hence, if we think that visual space – which *includes* pictures as well as the objects they represent – is describable in terms of Riemannian geometry, then to make picture understanding possible, visual space must be structured according to Euclidean geometry. What matters in recognition is not an exact match in shape and size; hence this reasoning should not be taken too seriously. Nonetheless, this mathematical requirement accords with a result of our experiment (Indow & Watanabe 1984). Frontoparallel subspaces exhibit Euclidean properties despite the fact that the horizontal plane along the depth dimension is better described as a hyperbolic space (Indow 1979; 1982). Because our visual space is so structured (whatever its basis), the possibility of drawing sketches is taken for granted and human beings have developed Euclidean geometry. This may not be so for primitive tribes. It is a psychophysical problem to make explicit the structure of visual space and the processes supporting that structure, whereas it is an anthropological problem to gain insight into what experience or learning is responsible for bringing about this structure.

On the rationale for cross-cultural research

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This commentary, concerned with some metatheoretical issues, is peripheral to the excellent survey of findings presented by Deregowski and does not affect its substance. It deals only with some implications of his conception of cross-cultural research contained in two key passages, the first being the following:

> Different cultural groups are sources of information about essentially the *same phenomena* [my emphasis]. . . . A psychologist attempting to understand the phenomena exploits these fortuitous differences in

the same way he exploits the high breeding rate . . . of the fruit fly . . . or . . . the simple organization of the visual system of the octopods. (sect. 1, para. 2)

The expression "same phenomena" is ambiguous. If it means overt behaviour, such as responses to pictorial material, then as very fully documented by Deregowski himself, the phenomena are *not* the same. If it refers to some underlying and presumably universal process one knows to be the same in all humans, then why take the trouble to face the difficulties and discomforts of the field?

The analogy of the fruit fly and the octopod is also inappropriate, for it suggests the possibility of greater simplicity and enhanced control. In fact, however, precisely the opposite is true: Cross-cultural work, far from making life simpler, usually introduces *greater* complexity and allows *less* control.

Why, then, embark upon cross-cultural research? The answer, rightly given by Deregowski, is that mainline Western psychology deals with a restricted set of phenomena, not altogether unfairly castigated as "the psychology of the college sophomore." Western theories fail to take into account types of behaviour rarely if ever found in Western industrial countries, and certain problems are never encountered.

As regards the first point, Deregowski demonstrated the inadequacy of Gibson's (1978; 1979) theory on the basis of cultural data. The second one is illustrated by Hudson (1960), who stumbled upon the difficulties experienced in some populations with pictorial depth perception. This constituted the *discovery* of one of the central issues of Deregowski's work, which has been greatly clarified by his many ingenious studies. Thus one of the important functions of cross-cultural investigation is to document variations in behaviour and then try to account for them by hypothesis generation and subsequent testing. It is for the latter purpose that cultural/ecological variations can be selected for conducting quasiexperiments, as in the studies of Segall, Campbell, and Herskovits (1963; 1966).

Deregowski's questionable assumption of the classical Cartesian model surfaces again in his penultimate section:

Available data do not allow us to evaluate the relative magnitude of genetic and environmental contributions to perceptual skills. . . . Nor are data that could help us to clarify some of these issues likely to become available. The words *culture* and *cultural* repeatedly used here are not used in a purist sense. They do not imply experimental control of the environmental and genetic effects, such that the variations observed could be said to be purely cultural. These two intruding factors were present in all the studies reviewed and may therefore have affected the findings. (sect. 12, para. 1)

The somewhat apologetic phrasing seems to suggest that these are shortcomings that ought to be remedied, though this is not likely to happen, presumably for practical reasons. Deregowski's apparent aim would be to get rid of the "intruding factors" in order to identify the effects of "purely cultural" variations.

Such an aim is probably an illusory one. As far as genetics is concerned, one need only recall the unresolved debate as to the extent, if any, to which the sex difference in certain spatial-perceptual skills has a genetic origin to realize how hard it is to isolate genetic factors. [See McGlone: "Sex Differences in Human Brain Asymmetry" *BBS* 3(2) 1980; and Benbow: "Sex Differences in Mathematical Reasoning Ability" *BBS* 1(2) 1988.]

Now, it could be argued that this is merely due to the absence of suitable methods, methods that could be elaborated in the future. But when it comes to relationships with cultural variations, the problem becomes a predominantly conceptual one, incapable of any technical solution. One of the main reasons is the fluidity of meaning of the terms "cultural" and "environmental," with the consequent absence of any clear demarcation line between them. Consider, for example, the "carpentered world" hypothesis, in which that world is a culturally created part of the physical environment; hence the common use of the term "eco-cultural." In any case, even if that problem did not exist, "experimental control of the environmental and genetic effects" is not practically feasible with humans, and therefore the disclaimer is unnecessary.

Thus Deregowski had no need to be apologetic for failing to reach an unattainable goal, especially because he has made such a solid contribution to our understanding of the problem area. He has also outlined a promising path to be pursued in his proposed model of component skills. The task will be to identify these skills analytically and to relate them to what are perhaps best called different learning environments. This is a more modest goal, but one that seems attainable.

Universals of depiction, illusion as nonpictorial, and limits to depiction

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Deregowski argues that 2D images may represent 3D objects for two distinct reasons: First, they contain cues that lead "indirectly" to the perception of a 3D object without evoking the "illusion of space." He gives as examples a silhouette picture of an elephant and a stick figure of a man. Second, 2D images may evoke the illusion of space "directly," without arousing recognition of an object. As examples he gives impossible figures. He says these have 3D cues.

Deregowski's review of the cross-cultural literature is very valuable. Notably, he points out that some populations may initially fail to recognize a picture. As their examination of the picture is prolonged, recognition is achieved, without need of training. He notes that this process is almost certainly like a Westerner's initial puzzlement with fragmented figures such as Street's (1931) – and I must add Mooney's (1954) chiaroscuro figures (shape-from-shading displays).

Here, I will take up Deregowski's notion of recognition-based pictures, versus 3D-cue pictures and his use of geometrical illusions; I will also hazard a suggestion about fragmented chiaroscuro figures.

On recognition and 3D cues: It is important to realize that all the pictures Deregowski uses are based on variations in reflectance of a surface. The variations are chiefly contours (abrupt change in lightness or reflectance) and lines (two changes in lightness, close together, elongated, and parallel). The eye readily accepts these as depictions of occluding edges of flat surfaces, occluding bounds of rounded surfaces, corners (changes of slant), and parallel combinations of these, such as wires and cracks, ridges and ruts. That contours and lines stand for these features of surface layout is apparently an unlearned property of vision (as shown by the evidence Deregowski considers) and haptics (Kennedy 1983).

One might define a line or contour as ambiguous, because it can have several referents. We might then hypothesize that something is needed to disambiguate it. It could be disambiguated by its presence in a form such as a silhouette or stick figure. This does not mean, however, that these two routes function very differently. The end results are the same: The line or contour depicts one of its surface-layout referents. Indeed, *neither* recognition *nor* cues are necessary. A squiggle or closed form that does not allow recognition and does not possess information about spatial layout can be seen as a depiction of a surface layout (a hole, a flat form, or a bulky unfamiliar object are examples).

Deregowski refers to the result of depiction as "the illusion" of space: One might call this "the appearance" of space, because illusions are deceptive, and depiction usually is not – one sees space, and flatness simultaneously, and is not deceived. Pictorial depiction is bicameral, two contradictory things simultaneously.

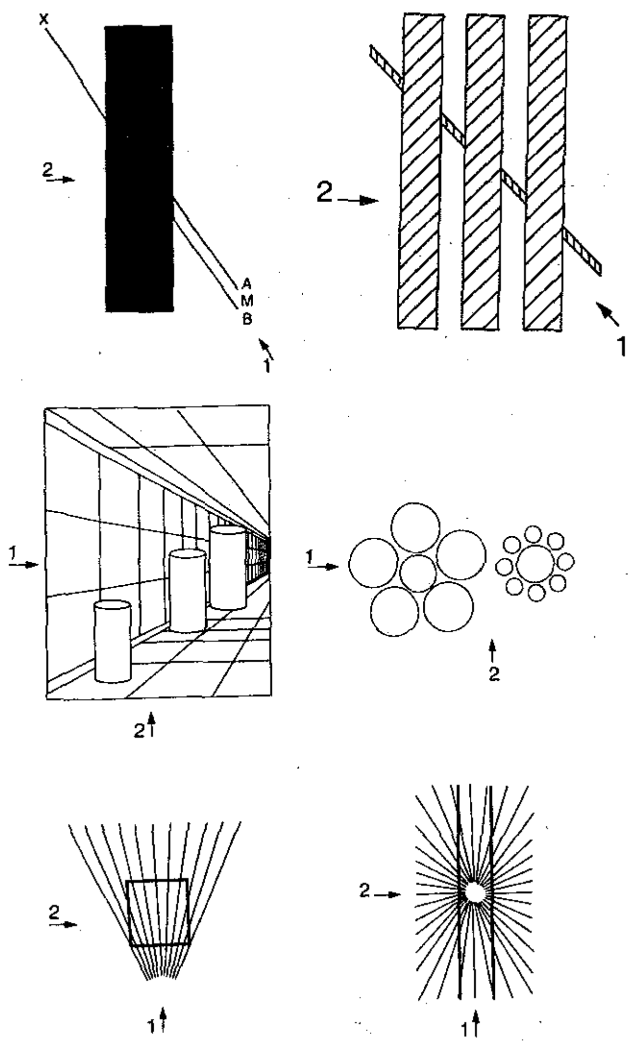

Figure 1 (Kennedy). Six standard illusions. These should be viewed on the Normal, *the line perpendicular to the display*, then with the display tilted, at a glancing angle of c, 10°–15°, along the direction of arrow 1, and then from the direction of arrow 2. The illusions are dispelled by peripheral adjustments modifying angles projected by the elements of the display.

It may be a great mistake to take illusions to be basically pictorial. An alternative view is that they are creatures of peripheral processes. They may be readily dispelled by peripheral adjustments, *such as changing the slant of the display.* Figure 1 supports this view. Viewed on the Normal to the display surface these six standard geometrical illusions create the appearance of misalignment, differences in size, and variation from parallel lines to tilted or bowed lines. But viewed from a low glancing angle *along arrow* 1 (*and sometimes arrow* 2) with a tilted display, the illusions are dispelled (Robinson 1972; Kennedy 1987).

Lines and contours can engender the appearance of variation in depth and slant, but peripheral adjustments of Figure 1 *suggest that this is not the modus* operandi of illusion. Let us also note carefully that lines and contours do not simply stand in for any perceptible variation, so far as vision is concerned. Some variations that vision uses are very poorly triggered by *lines* or by contours between light and dark if the contour is misoriented (*light to dark, when* dark to light is needed).

Consider Figure 2. This is a positive print (where light stands for illuminated and dark for shadowed), a negative (where light stands for shadowed, and dark for *illuminated*) and *an outline* (where line stands for shadow-illumination boundaries). The positive is readily processed, the negative less so, and the outline probably even less so. Figure 2 shows that variation in illumination gives rise to full shape-from-shading analysis only when contours between *patches are present and correctly* oriented. It is distinctly possible that this limit on vision is a universal.

I have proposed three notions: Pictures are based on universal capacities to use line and contour for surface layout. Illusions are *peripheral in origin. Only oriented* contour evokes chiaroscuro (shapes-from-shading) processing. How do these three notions apply to the important evidence for different levels of pictorial functioning in various populations? I suggest that what is probably varying across cultures is the use of organizational principles.

Notice that line and contour elements are arranged in displays following many principles: Botanical, biological, geological, geometrical, astronomical, cultural style, carpentered, mechanical, weathered . . . the types of form are myriad. My own experience with various types of music indicates that principles of form are often only slowly mastered. Everyday experience with different types of housing (or types of sport) shows that variation which *is initially overlooked as unimportant* gradually takes on distinctness and significance. The Inuit are said to distinguish many types of snow!

We learn about principles of organization, not just details of organization, of course. I recall the new look of the world after

Figure 2 (Kennedy). Chiaroscuro displays. A positive, a negative, and an outline version of the same pattern.

reading about topography. Recent advances in scale-free geometry have made many of us aware for the first time of similarities between coastlines and Dow Jones patterns. Reading about different projection systems is very enlightening. As a result, we group shapes in new ways. We extrapolate and interpolate in new ways. We notice, in becoming expert in any area, both details and grand patterns we had ignored before. This principle may be the larger truth behind the vague notion that visual environments are different for different populations.

One codicil is worth adding: Gombrich (1982) noticed that the faces of bewigged portraits from the eighteenth century all looked somehow the same. Remove the wigs and they become individuals. This example may be apply to the Deregowski finding that the material of a display can hold visual attention so much that other aspects of the display go unnoted. Distractions are difficult to bypass in vision, it seems, even by highly trained eyes like those of Gombrich.

In short, there are universals in pictorial representation, including limits to depiction, there is considerable cross-cultural variation in the use of principles of form, and visual distractions can be road blocks to processing.

Real space and represented space: Cross-cultural convergences

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Cross-cultural research on picture perception is replete with confusing and apparently contradictory findings. Deregowski's review goes some way towards introducing order to this chaos. Particularly helpful is the distinction between 2/3d and 2/3i stimuli. With a little refinement this distinction may serve an even more integrative function than Deregowski acknowledges and render redundant the complex and relatively arbitrary model of perceptual skills depicted in Figure 25 of the target article.

With respect to information for three-dimensionality, pictures can vary from those that contain the full range of static depth information to those in which the information for depth is highly coded, symbolic, and conventionalised. The former correspond to Deregowski's 2/3d category, although the target article contains no examples of such stimuli; the latter are more akin to his 2/3i category. If, however, we treat this distinction as referring more to a continuum than to a dichotomy then we have a basis for ordering pictorial depth perception tasks with respect to (a) the amount of transfer to be expected between depth discrimination in three-dimensional space and pictorial depth discrimination; (b) the accuracy of performance at different points during ontogeny; (c) the ease of learning/training for improved performance; (d) the probability of cross-cultural differences in performance on specific tasks. If we refer to the proposed dimension as the P(hotographic)–S(ymbolic) continuum, then we can propose the following arguments: The closer particular stimuli are to the P end of the continuum, then the greater the transfer, the earlier in ontogeny one can expect accurate performance, the greater the ease of learning/training, and the lower the probability of cross-cultural differences. These arguments will now be developed further and illustrated from research findings.

In the three-dimensional world, information for the distribution of objects in space is available from binocular disparity and motion parallax; additional spatial information is available from linear and aerial perspective, texture gradients, superimposition, elevation, visual angle, and shading. The latter, universally available static sources of depth information, can be reproduced, in photography, painting or drawing, on a plane surface to create a two-dimensional representation of a three-dimensional scene. Because there is such isomorphism between the spatial information contained in P pictures and the scenes they represent, it would be surprising if there were *no* transfer of skills and strategies from the latter to the former. In other words, depth in P stimuli can be perceived directly. Even P pictures, however, contain information for flatness (provided, for example, by the picture boundary, surface texture, and the absence of parallax). Thus, the perception of pictorially represented space requires the observer to ignore the cues for flatness in favour of those for three-dimensionality.

Adult viewers from a variety of cultural backgrounds are highly adept at perceiving the spatial relationships between objects in P stimuli and at perceiving pictorially represented depth, at least to an ordinal scale. Even in relatively pictureless cultures people are able to understand P stimuli after some little effort and/or training (Forge 1970, pp. 287–288; Laws 1901; Deregowski et al. 1972). On the other hand, children are more likely than adults to be influenced by the information for flatness; the accuracy of young children's judgements of pictorially depicted size and spatial relationships is much more enhanced by the concealment of flatness cues that is that of adults. However, performance in this respect is highly similar among children from cultures as contrastive as those of Malawi and North America (Ireson & McGurk 1985).

Deregowski dismisses rather lightly the extensive range of difficulties associated with the Hudson test (cf. Jahoda & McGurk 1974a; 1982) and appears to imply that the pictures represent unambiguous examples of his 2/3d category of stimuli. These pictures certainly do not afford direct perception of spatial relationships in the way that the P stimuli referred to above do. The cues to depth that the Hudson pictures contain are nonveridical (there is no possible space to which the pictures could correspond) and conventionalised. Thus, they are located away from P and towards S on the continuum postulated here and perception is mediated rather than direct. Accordingly, performance on the Hudson tasks can be expected to be developmentally delayed compared with performance on more P-like tasks and cultural differences are to be anticipated. This, of course, is exactly what the literature reveals (Jahoda & McGurk 1974a).

On tasks involving stimuli that can be argued to lie between true photographs and the Hudson materials, such as those used by Jahoda and McGurk (1974b), one would expect cultural differences in performance to be reduced and, again, this is indeed the case.

Beyond the hypothetical point occupied on the P–S continuum by the Hudson materials lie pictorial stimuli that are increasingly abstract and conventionalised and require culturally specific knowledge for their interpretation as three-dimensional surrogates; road traffic symbols are among the examples that come to mind. Because of their conventionality and the fact that their correct interpretation is dependent on appropriate socialisation experiences, cultural differences in responses to such materials can be anticipated to be large.

As argued earlier, the postulation of a P–S continuum of pictorial depth stimuli can accommodate Deregowski's case for a relationship between the perception of spatial distribution in the three-dimensional and representational worlds. It can also accommodate the hypothesis that there may be little or no overlap between the processes involved in the discrimination of stimuli from the P pole compared with the S pole of the continuum. The former can be thought of as bottom-up, the latter as top-down processes; it is acknowledged, however, that for stimuli from the centre of the continuum both kinds of processing may be involved. The only feature of Deregowski's model to which the present proposal is not sensitive is his claim that different cultural groups "use different skills to perform the same perceptual task." This claim, asserted rather than demonstrated, can surely only apply to cultural differences in the construction and interpretation of S (2/3i) stimuli, in which case it is of little theoretical consequence. Otherwise it must rest upon the confusion, which emerges towards the end of the target article, between perceptual skills, picture viewing strategies, and artistic/cultural convention; on this ground it can be ignored.

The archaeology of space: Real and representational

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The representation of space, when seen in cross-cultural perspective, is far more complex than its presentation in Deregowski's target article would suggest. Such symbolization is, above all, a problem of "text" and "context" rather than one of 2D or 3D responses to pictures and illusions designed for literate, Western subjects. The cultural context of image making, image content, and image meaning are all important. The depiction of space can be metaphorical and metonymical (in the sense meant by Johnson 1987) and need not be purely representational and iconic. Moreover, "real" space itself can be endowed with representational qualities through the built environment (Preziosi 1979).

Functions (Eco 1976) corresponding to all three classes of signs, in the sense meant by Peirce, are a part of the art of the later Pleistocene in Europe and Africa. The so-called Upper Paleolithic "cave art" is representational and iconic; line and color are used to represent volume and spatial dimensions of animals and other living things (Davis 1986; 1987; Leroi-Gourhan 1965). In addition to these iconic signs, there are also nonrepresentational elements – symbols and indices – in both the cave and rock paintings as well as in what has been called "portable art" (Conkey 1987; Leroi-Gourhan 1982; Marshak 1985). The structure and the content of this art is not unitary in either space or time, which suggests that the cultural context of its production and consumption are important. Yet the capacity for artistic production, like the capacity for language and the capacity for writing, all seem a part of the "hominization process."

To move into our time, work by Nancy Munn among the Walbiri, a hunter-gatherer group in the Western Desert of Australia, clearly illustrates the importance of cultural context in the analysis of pictorial art (Munn 1986). The Walbiri draw sophisticated "maps" of their traditional territory. The elements of these maps, however, are symbolic and indexical, not iconic. Geographic features of the Walbiri landscape are endowed metaphorically with the exploits of the ancestors; these exploits are then worked into a narrative that is produced in pictorial form as a map of the landscape. The investiture of space with social and metaphorical structure and meaning is common to most societies. Many societies, however, do not reproduce this knowledge in the form of drawings and paintings.

Most societies do represent social relations in the structure of the built environment. "Real space" is often organized symbolically. When, for example, Andrianampoinimera unified the Merina state in the central highlands of Madagascar in the late eighteenth century, he rebuilt the sacred capital, Ambohimanga, to conform to sacred cosmology and traditional social relations (Kus 1979). When the late Mayor Daley of Chicago championed "urban renewal" he also created the vertical ghetto to take the displaced poor: a real third dimension that today has potent symbolic force. Many hunter-gatherers arrange their camps along social and symbolic lines; most early states separate sacred from profane spaces. Such considerations go far beyond the "ecological" and the "carpentered world" hypotheses.

Thus the nonrepresentational pictorial symbols, which Deregowski designates 2/3i (indices and symbols), can be signs of 3D space without directly representing such space. They are important, as the author notes, because of their role in narrative, and narrative is dependent on cultural context. Likewise, 2/3d representations (icons) must be judged first in terms of their iconicity for individuals from a particular culture, not as signs with universal validity for testing perception.

Anthropology is developing an interest in cognition and the cognitive sciences, witness two recent special issues of the *American Ethnologist* on "symbolism and cognition" (vol. 8, no. 3, 1981; vol. 9, no. 4, 1982). One can hope that reciprocal interests in anthropological methods will develop among psychologists who do cross-cultural research and comparisons. Cultural context is important to their work too.

Plea for more exploration of cross-cultural cognitive space

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In addressing the intriguing question of how visual space is mentally represented across and by different cultures, Deregowski has successfully avoided trying to be everything to everyone, although the results and inferences presented are reminiscent of:

> It isn't that they can't see the solution. It is that they can't see the problem.
>
> Chesterton (1929)

a point that will be considered later.

Gregory (1970) has stated that all pictures are paradoxes in their own right because we (at least Westerners . . .) know them to be flat yet remain convinced of the representation of real space (Deregowski's 2/3d space) within them. Deregowski usefully categorises pictures as 2/3i and 2/3d, which enables him to discuss them and their relation to real space from a central perceptual viewpoint. Such a viewpoint may be considered intermediary to such sensory characteristics as stereoscopic acuity and cognitive effects as spatial memory, which evokes strong cognitive connotations. Although stereo-acuity would convey information about individual differences, it might be thought that because it is a fundamental sensory characteristic it can tell us little about cross-cultural perception. However, another sensory "given," that of visual acuity, might be influenced by different environments. The "oblique effect" reported by Annis and Frost (1973), about which there is some controversy, refers to the lowered visual acuity for oblique lines compared to vertical or horizontal ones experienced by students who live in an urban environment. Cree Indians, whose environment contains a more completely representative sample of lines in all orientations, do not show such an acuity difference. Cross-cultural studies involving illusions such as the Müller-Lyer and Ponzo which, as Deregowski shows, are influenced by perceptual experience might also be influenced by the oblique effect because both illusions contain oblique lines. However, because real space is both temporal and spatial (it may be considered dynamical), we interact with it, manipulate it, and in turn are manipulated by it; our knowledge of space extends well beyond a consideration of depth cues and constancy and the use of the illusions mentioned above is perhaps only applicable in studying the static parameters of space. A cognitive view of space is thus more appropriate, a view that considers what we "do," "have done," or "intend to do" in real space; hence 2/3i and 2/3d representations cannot help but be viewed in such a light with the benefit of intelligent perception that goes beyond simple awareness.

For humans or machines to make sense of space, real or represented, they must solve a series of problems. What is this object? What does it do? What does it look like from the other side? A suitable complement to the use of illusion in cross-cultural perception studies might be the use of interactive phenomena where subjects mentally manipulate aspects of space. Shepard and Metzler's (1971) mental rotation tasks with polyhedra represented (in Deregowski's terms) in 2/3d require the use of imagery and problem solving. Such reasoning could be extended to such temporospatial manipulations as are used in unravelling knots or topological puzzles, or to the use of the "Flatland" (Abbott 1884/1950) effect in mentally tracing the shapes produced in 2D when a solid passes through a plane. Such tasks would not only be useful in requiring the viewer to solve the problem, but also, like any game, in revealing to an independent observer the strategies used. Deregowski touches on the manipulation of space several times when he mentions spatial memory; he discusses perceptual skills briefly and then, at greater length, the use of various construction and replication tasks. One such task, using callipers to replicate angles shown in 2D as "flat" without depth cues and as "solid" in oblique projection (Deregowski & Bentley 1986) meets both imagery and problem-solving requirements. However, Deregowski mentions that the "flat" figure could only be seen as flat. This may not be the case and could well affect the experimental outcome; the figure can be considered multistable in depth because it forms the basic element of a Necker Cube and exhibits apparent depth reversal, in addition to appearing "flat." In fact, Deregowski's awareness of such a problem is evident when he writes "the same picture may be variously seen as 2D, 2/3i, 2/3d or as a meaningless blotch." He also alludes, in relation to a construction task, to more cognitive influences: "part of the perceptual difficulty probably lies in the perceived *intent* of a stimulus." Such a statement could well apply to Hudson's figures (Figure 18), where a tableau of depth cues, hunters, deer, and elephants are shown as 2/3d. Do natives throw spears at elephants, even small ones? If not, then the evaluation of the scene is questionable.

It will be obvious that Chesterton's remark quoted earlier could be made by any culture about any other, and that Sherlock Holmes's injunction, "with all these data you should be able to draw some just inference" (Conan Doyle 1890), is far from being met.

Pictures, maybe; illusions, no

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The basis for my commentary is Deregowski's statement: "For example, the perception of certain illusions such as the Ponzo (Figure 8) or the Müller–Lyer (Figure 22) involves the immediate transfer of 3D spatial skills into the realm of pictures" (sect. 11, para. 8). Although one can debate the need to learn and accept pictorial conventions (largely European, but possible Oriental) for representing the three dimensions of space, the underlying determinants of the classic geometric illusions mentioned most probably have nothing whatever to do with "3D spatial skills." Indeed, the history of Western graphic art has been the continuous reconceptualization and reinvention of three-dimensional space applied to a two-dimensional medium. I will cite some references to refute Deregowski's contention. Next, I will suggest other determinants of the susceptibility to illusions, and finally I will propose an experimental test of the opposing views.

It is interesting that within the data reported by Segall et al. (1966) are the seeds of the destruction of their "carpentered world" hypothesis. Just as in the West, among Americans of European ancestry, the magnitude of the Mueller–Lyer illusion declines with age through childhood (Pollack 1963; 1969; 1970a; 1970b). In other words, increasing perceptual experience of the kind supposedly required to produce the illusion apparently does just the opposite. In addition, the study of Ghanaians in different environments by Jahoda (1966) failed to produce different illusion magnitudes. Fisher (1968), in a series of demonstrations, showed over and over again that altering depth cues and orientations that might contribute to depth perception has no effect on the magnitudes of either the Mueller–Lyer or the Ponzo illusion. Finally Leibowitz et al. (1969) report no cross-cultural differences in the magnitude of illusion produced by the basic Ponzo figure although there are considerable differences when pictorial perspective cues are added.

Drawing on the work of Wald (1945), Eckhardt (1966), Fitzpatrick (1964), and Ishak (1952a; 1952b) dealing with brightness thresholds as a function of wavelength and fundus pigmentation, I suggest that primary geometric illusions (Pollack 1963; 1969; 1970a; 1970b; 1972; 1976) depend upon the sensitivity of the visual system to brightness or lightness contrast. In two studies (Pollack & Silvar 1967; Silvar & Pollack 1967) we showed that the fundus pigmentation of black Americans was in general darker than that of whites and that the magnitude of the Mueller–Lyer illusion was inversely related to the density of that pigmentation. The two darkly pigmented white and one lightly pigmented black crossovers behaved like their pigment, not their racial mates. Our results were supported by cross-cultural research reported for a group of societies (Berry 1971) and for a black African–white Scottish comparison (Jahoda 1971). A series of studies with the Mueller–Lyer illusion (Ebert & Pollack 1972; 1973a; 1973b; Ebert 1976) produced the same results with all white bimodal pigment distributions. In two studies (Sjostrom & Pollack 1971a; 1971b), we were able to simulate pigment darkening with yellow filters; this reduced the magnitude of the Delboeuf illusion. Finally we showed that Kohs's Block Design performance in blacks was depressed if we used the blue and yellow faces rather than the red and white ones (Mitchell & Pollack 1974). A follow-up study (Mitchell et al. 1977) demonstrated that having white subjects view the blocks through neutral density filters mimicked the effects on black subjects without filters. It appears clear, therefore, that a variety of perceptual phenomena can be accounted for by differences in genetically determined optical differences rather than culturally conditioned cognitive processes. It is interesting that the cross-cultural differences cited by Deregowski and by Segall et al. (1966) all involve peoples who are considerably more deeply pigmented than Europeans, a fact that, at best (for their case), involves a confound of pigmentation with culture.

If we shift our focus to perceptual displays whose contours are produced by hue contrast in the absence of lightness contrast, we have a situation that offers the possibility of avoiding the confound, and, consequently, offering the opportunity to test for cultural differences without concern for genetic racial effects.

I found (Pollack 1965) that hue detectability thresholds do not change with age through childhood, although there are distinct, consistent hue differences. The same pattern obtains for visual acuity as determined by minimal bar separation (Skoff & Pollack 1969) or the detection of a single line (Kelton et al. 1978). By the same token, Mueller–Lyer illusions whose contours were produced by hue contrast alone, neither decline through childhood (Pollack 1970a; 1970b) nor increase through adulthood (Youn et al. 1987) the way their lightness contrast counterparts do. Even simulated aging in young adults produced by viewing through a combination of yellow and neutral density filters results in no diminution of illusion magnitude with hue contrast figures (Youn & Pollack, submitted). Even allowing for lessened black sensitivity to short wave light (Jahoda 1971), figures constructed of red, yellow, and yellow-green lines on neutral gray grounds of equal lightness should provide admirable stimuli for a test of cross-cultural differences in the magnitudes of geometrical illusions. I offer this suggestion as a friendly challenge to cross-cultural perceptionists who have access to exotic populations, provided only that they match our viewing conditions. I contend that the determinants of classical geometrical illusion magnitudes lie in the interaction between their contour patterns and the condition of the primate eye that responds to them. Thus, they are universal visual phenomena largely independent of culturally induced cognitive processes.

Many a slip 'twixt external and internal representation

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Deregowski has classified visual skills into two basic types (Figure 25): 3D spatial skills and representational skills. Is this particular division valid and useful, and is two the right number of types?

First, it is important not to confuse what Deregowski means by representation, that is, external symbolic representation, with the internal representations discussed by cognitive psychologists, namely, a sort of language within the brain (e.g., Kant 1781; Fodor 1975; Kitcher 1987; Fodor & Pylyshyn 1988). The external representational skills that enable an individual "to make optimum use of pictures" almost certainly require the construction of internal representations; these in turn have to be interpreted. Thus the external representation has to be mapped onto an internal representation that in turn is mapped onto, linked in with, or is an intrinsic part of the semantic knowledge-base. Both stages may depend on experientially or culturally acquired processes.

How, one wonders, do these processes develop; for example, how does region E of Deregowski's Figure 25 come into existence? Is this a matter of learning purely arbitrary symbols, like learning to read Chinese characters, or is it really a degraded form of 3D spatial skill? Thus Deregowski gives the fact that a stick figure drawing can be seen as a representation of a man as an example of a region E skill – but in this case there is a similarity between the drawing and a man seen from a distance or in poor lighting. (The work of Johansson (1975) shows that even very impoverished cues in the real world can still be adequate to enable identification of an object, especially a human being.) It is difficult to make sharp distinctions between purely arbitrary pictorial conventions, degraded or impoverished depictions, nondegraded depictions, and degraded or impoverished real views of objects. There may be a continuum of skills here. Note that in the history of art and writing, realistic depictions change over time into nonrealistic ones (e.g., Gregory 1981, p. 52). This change often involves simplification. The idea that the human figure can be simplified into a stick figure is certainly compatible with Marr and Nishihara's (1978) notion of how such an object is represented internally, and the importance of the compatibility of visual input with internal coding is supported explicitly by Boselie and Leeuwenberg (1986). A study of brain-damaged patients viewing objects' silhouettes from different angles, however, suggests that it is the number of cues visible in the picture that determines the ease of recognition, rather than the similarity between the picture and a prototypical internal representation (Warrington & James 1986). In sum, the changes made in developing from realistic to symbolic art might consist of regression to a canonical view that resembles the internal cognitive encoding, or it might consist of an increase in the salience and/or number of critical cues and features (and/or a reduction in redundant or conflicting information). Conversely, learning to make drawings may proceed in the reverse direction; witness the primitive figures drawn initially by the Tallensi (Figures 3b and 10) and by children (Freeman 1980). Whatever the nature of the change, the dichotomy between two types of external representation skill – skills that overlap with real-world spatial skills and skills that do not (Figure 25) – is called into question. These two types can better be regarded as extremes along a continuum, rather than discrete classes.

Can any useful categorization of the skills involved in picture perception be made? Deregowski distinguishes between 2/3i and 2/3d images, which evoke concepts of three-dimensionality either via object recognition or "directly." This dichotomy would be better couched in terms of the internal processes of cognition. Some cues lead to object recognition and retrieval of information (3D and other) from memory, whereas other cues are used for "scaling," that is, perceiving the orientation, distance, location, shading, luminance, and so forth, of the object (Gregory 1970). Visual illusions can then be classified according to the types of miscues provided: These can be cues to object identity or to scaling, and the cues can be impoverished, false, ambiguous, or conflicting. Thus for object identification, impoverished cues are available in the Gollin and stick man figures (Figure 3b), false cues lead to the perception of illusory objects such as the Kanizsa triangle, ambiguous cues are provided in the Rubin vase (cf. Figure 7), and conflicting cues are exemplified in the devil's tuning fork (Figure 5). With respect to scaling, impoverished cues are available in the ellipse figure (Figure 24), false cues in the Ponzo illusion (Figure 8), ambiguous cues in the Necker cube and Schroder staircase, and conflicting cues in Escher drawings of staircases. There are thus $2 \times 4 = 8$ types of illusion. The false, ambiguous, and conflicting cue categories can perhaps be collapsed, leaving only four types of illusion: inadequate (too few) cues versus overadequate (too many, spurious) cues – with those cues being cues to object identity or to scaling. Each of those cues can be acquired through environmental experience or through cultural convention, to varying degrees depending on the extent of penetration of the cue into culture, as explained above.

Pictorial representations can thus be analysed into components, and cross-cultural studies can focus on the nature of the components that differ from culture to culture. One interesting question is how members of different cultures respond to scale models of objects. These contain three-dimensionality while still maintaining many of the attributes that pictures have although real objects do not (for example, they are usually not the same size as the real object, they do not have the same surface texture, and, unlike their actual counterparts, models of living creatures do not move or smell). More information would therefore be generated about why some people fail to see 3D in 2D representations if direct comparisons were made between the ability to recognize pictures, models (minature or life-size, realistic or symbolic), and the real objects that they represent.

Whither cross-cultural perception?

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Questions about the fixedness of perception have intrigued a variety of psychologists. Clinicians, for example, have been interested in the effects of psychopathology on perception, among other processes. Developmentalists have looked for perceptual differences between children and adults. Specialists in personality have studied whether different kinds of people perceive the same situation in different ways. Part of the motivation underlying all of these pursuits has been the very important question of whether the basic units of perception are species-invariant or whether even perception, that seeming bedrock of cognition, admits to variation in the manner in which memory, attention, imagination, and the rest so obviously appear to vary. The study of perception in different cultures provides a convenient entree to this question as well, as Deregowski notes.

It has not been at all difficult to demonstrate that differences do abound as a function of development, personality, clinical status, and culture. The problem has had to do with making a persuasive case that the differences are indeed perceptual. Elkind (1969) found that young children described drawings like the one presented in Figure 15 in terms of individual elements rather than as a face (as older children were more likely to do). Is this, as the target article suggests, a perceptual effect? The difference might have more to do with how children interpret instructions, or what they pay attention to, or what they choose to comment upon. But, again, perhaps all of that is perception too.

A tack taken in addressing this problem has been to make use of tasks seeming to have wide consensual agreement as being perceptual ones. Gibson et al. (1962) had children make same–different judgments of pairs of letterlike forms differing on those features that differentiate real letters. In a similar vein, Segall et al. (1966) had various African groups respond to stimuli that produce visual illusions in Western adults, and Hudson (1960; 1967) assessed South African miners' judgments of pictorial depth. The motivation in all of this research was to look for perceptual differences. In each case, however, the authors' confirmatory conclusions came to be challenged on grounds that something other than perception might have been responsible for the results.[1] Hudson's research in particular has been subject to this criticism (among others), but the more important point is that the study of perceptual *differences* in general has proven very difficult.

The reason, in large part, can be traced to lack of agreement on appropriate boundaries for perception. The classical studies of cross-cultural perception were launched more than two decades ago when intensive, empirical study of perception was just beginning. Everyone "knew" what perception was, until research reports began to appear that revealed the extent to which consensual boundaries on the concept were chimerical. Without agreement on the data to be taken as perceptual, the study of cultural differences in perception appears to have foundered and given way to a different, more variegated set of questions about the psychological effects of culture.[2]

Deregowski would seem to agree with this assessment, but for somewhat different reasons. The chronology of studies in the target article details how the questions that originally motivated cross-cultural research have undergone substantial revision over the years. An old question, for example, was whether South African coal miners perceive what is depicted in line drawings on safety posters; a new question is how Nigerian students' judgments of three-dimensional space compare when made from models versus line drawings of those models (Nicholson & Seddon 1977). Unless I missed it, Deregowski doesn't directly address the issue of why this change came about. He does, however, make a revealing comment about a failing of the original project: "Available data do not allow us to evaluate the relative magnitude of genetic and environmental contributions to perceptual skills."

I find this revealing because it illustrates how the origin of *individual differences* was the major motivating factor behind the original project; the nature of perception itself was of considerably less concern. Ironically, in my view, the latter proved so troublesome that interest in the former could not be sustained. The shift in emphasis implicit in the model presented in the latter part of the target article can be seen more clearly as a move away from perception, because of the largely unanticipated problems encountered, than as a disaffection with cultural differences.

NOTES

1. See Caldwell and Hall (1970) for a decidedly nonperceptual interpretation of Gibson et al.'s findings.

2. This is not to imply that two decades of concerted research have produced anything like consensus on the sorts of things to be taken as perceptual. In fact, some indications suggest the opposite. Witness the near-consanguineous dispute in the comments of Kellman (1988) and Gibson (1988) on Spelke's (1988) interpretation of her dazzling findings with infants. Questions about individual differences in perception seem a very long way off.

Cultural determination of picture space: The acid test

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Deregowski uses the impossible fork (or "trident") figure to establish that viewers from different cultures see picture depth differently. This is a bad test, however. The fork cannot be assumed to indicate anything about depth perception.

In my own discussion of the impossible object figures (1983), I argue that two distinct types of flaws can be sources of impossibility. The fork is a complicated figure possessing both these flaws.

On the one hand, the fork is a *depth impossible*. As Gregory (1970) pointed out, the fork's middle prong lies both in a plane below that of the outer two, and in the same plane with them. It is in two places at once. Thus the fork cannot be made of wires bent into depth.

But the fork is also an *impossible solid*. As Kennedy (1974) showed, surfaces forming the "window" at one end of the fork turn into air space at the other end. The fork lacks a continuous edge. Thus it cannot be cut from a flat sheet of paper, nor can we color it in, choosing one color for the solid parts and one color for air space intervening between these parts.

Deregowski thinks that viewers who are confused by the fork – and so find it difficult to copy – thereby give evidence of being normal perceivers of three-dimensional pictures. However, because the fork is impossible even as a *flat* object (a paper cutout), viewer difficulties with the figure cannot be interpreted as Deregowski supposes.

As this oversight about the fork leads us to expect, Deregowski generally fails to distinguish cues for surface qualities and cues for geometrical depth (see also Deregowski 1969; 1971c; Young and Deregowski 1981). Cues of the first sort (e.g., vertex types catalogued by computer scientists) enable us to see object features such as surface on one side of a figural contour, or cracks, or wires. Cues of the second sort (e.g., convergence, perspective foreshortening) enable us to position objects in geometrical space.

Deregowski also fails to recognize that the latter cues are said to have special power – are said to produce, under the right conditions, a trompe l'oeil convincing to *all* viewers. The omission is important, especially considering the case he is trying to argue. For as we shall see, one needs to recognize the special status of geometrical depth cues if one is to choose the best test for showing that picture depth perception is culturally determined.

Instead, in his characterization of picture types 2/3i and 2/3d, Deregowski embraces a distinction much like the one Wittgenstein (1958) makes in his discussion of "aspect perception." For Wittgenstein, pictorial images range from less to more successful imitations of reality – for example, from a bare triangle to the Necker cube. Although no one in any culture would take the triangle for a mountain, the Necker cube *is* "connected with the possibility of illusion" (p. 208).

Yet for Wittgenstein, and also for Deregowski, figures do not create illusions that are automatic and universally experienced. Because to see an object in a picture is not to perceive the object directly, it must always be true that viewers *can* see the picture as just a flat arrangement of colors and shapes. In fact, a viewer who can *only* see such an arrangement cannot be considered defective in normal spatial vision. As Wittgenstein says (p. 214), "this could not very well be called a sort of blindness."

Deregowski's Wittgensteinian bias causes him to seriously misrepresent Pirenne, whose views about picture depth perception are very different from his own. Discussing the illusionistic Pozzo ceiling, Pirenne seeks to establish the validity of the Renaissance theory of picture space (1970; 1975; see also Pirenne 1952). He quotes Leonardo: "Perspective is nothing other than seeing a place [or objects] behind a pane of glass, quite transparent, on the surface of which the objects which lie behind the glass are to be drawn. They can be traced in pyramids to the point of the eye and these pyramids are intersected by the glass plane" (1952, p. 172). According to the Renaissance theory, a picture can be made that is a *surrogate* of the object in that it sends to the eye a flux of light with geometrical properties closely resembling those delivered by the scene itself. Thus, under ideal conditions, there is no difference between seeing the geometrical picture scene and the real scene. The illusion should be automatic and universal for everyone with normal abilities to see the scene itself.

One of the ideal conditions required for this perspective "experiment" to work is: The picture's surface must be invisible. Hence Pirenne says, "The main point of interest in Pozzo's painting . . . is that the spectator is quite unaware of the shape, position and other characteristics of the painted surface itself. It is this very unusual state of affairs which produces the irresistible illusion of three dimensions in the scene represented" (1970, pp. 92–93).

The statement seems clear enough. Yet, unaccountably, Deregowski thinks Pirenne supports his own notion that the ability to see the "picture as a picture" is "crucial to the perception of pictures": "This phenomenon has been extensively discussed by Pirenne (1970) in the context of the perception of pictures that give particularly strong impressions of depth, such as the famous ceilings painted by Pozzo. Pirenne referred to the observer's awareness of the perceptual significance of the pictorial surface as *secondary awareness*" (sect. 6, para. 15).

In misreading Pirenne, Deregowski misses a chance to select the best test for establishing his own claim about culture's role in picture depth perception. As Goodman (1968, pp. 10–11) notes, Renaissance geometrical perspective is said to offer a standard of fidelity between picture and scene that transcends individual and cultural differences in experience. Clearly, then, Renaissance perspective is the dragon Deregowski needs to slay. He must bring his English schoolboys, Bantu laborers, and other cultural representatives to be tested in a Pozzo ceiling-like setting. And if, in this context, they still differ in their picture depth impressions, Deregowski will be well on the way to making a case for his cultural determination theory.

Cross-cultural research in perception: The missing theoretical perspective

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The tradition that *BBS* comments are fairly critical will be followed here. The criticisms expressed, however, should be seen in a proper perspective (2D or 3D?). Deregowski has conducted an impressive number of cross-cultural studies in perception. In our opinion his expertise is reflected in the overview provided.

Our major criticism of the target article concerns the lack of theoretical integration of the abundant empirical findings. In the empirical work there appear to be three (related) shortcomings that hamper the development of a coherent theory. First, stimulus characteristics such as 2/3i or embeddedness are not sufficiently distinguished from subject characteristics such as representational skills and 3D spatial skills. Second, much evidence has been cited in the target article to the effect that the medium of the response can have a modulating if not a limiting effect on the accuracy of the response; in Deregowski's own work good examples of this can be found (e.g., Deregowski 1971; Deregowski & Jahoda 1975). Systematic investigations should be undertaken to estimate the impact of both the stimulus and the response medium independently. Any theoretical framework that accounts for intergroup differences on perceptual tasks should encompass a distinction between the stimulus medium and the response medium as well as a delineation of their relationship.

Third, most of the work reviewed is rooted in what Cronbach (1957) has called SR-psychology, although the field could benefit from the implementation of elements typically associated with an RR-orientation. Thus, the "difficulty" of the tasks is an often neglected factor. Hudson's drawings (Figure 18) are far more complex than Deregowski's callipers (Figure 19). It is quite uncommon to find a measurement instrument in which the difficulty level has been varied substantially across the stimuli. An extensive and systematic analysis of the difficulty of perceptual tasks is badly needed. In addition, there is a lack of studies in which more than a single task has been administered. Deregowski's remark that "it is unwise to rely on a single measure for such a broad concept as perception of picture space" should be seen as a statement of intent rather than as a description of the actual state of affairs.

The development of a coherent theory will be facilitated by a study of the size of intergroup differences on various tasks, because not all kinds of perceptual tasks seem to be equally prone to show cross-cultural differences. The empirical evidence reviewed in the target article suggests an increase in such differences from perceptual constancies (notably size constancy) to visual illusions and in pictorial representations from photographic or technical drawings as used by mechanical engineers. Minor cross-cultural differences are reported for perceptual constancies, not infrequently pointing to superior performance by non-Western subjects (e.g., Reuning & Wortley 1973). The intergroup differences on visual illusions, which are commonly found, do not favour any cultural group systematically (e.g., Segall et al. 1966). With pictorial representations the pattern changes. The intergroup differences are often larger and usually point to better performance by Western subjects. More specifically, picture recognition tasks in which real objects are represented may well lead to cross-cultural performance differences. These will be more likely with schematic pictures such as Hudson's figures, whereas the recognition of schematic drawings such as those used by mechanical engineers gives rise to the most pronounced and systematic intergroup differences.

It might be tempting to speculate that cognitive load (as a subject characteristic) or task complexity (as its counterpart in the stimulus) accounts for the cross-cultural differences. The more complex the task, the larger the resulting intergroup differences. However, this cannot be attributed unambiguously to an increase in the cognitive load. Pictorial tasks also differ in what can be called "decontextualization." Going from object representations to the schematic diagrams of mechanical engineers, the ecological validity of the stimuli gradually decreases. Highly overlearned 3D skills have to be applied in a new context, 2D pictures. By definition, 2D recognition tasks imply the application of cues, originally learned in 3D perception, out of their natural context. Not all 3D cues can be represented in a 2D picture. The 2D pictures have only a limited validity with respect to the reality depicted. In recognition tasks using 2D pictures of 3D objects the subject has to recover the information lost in the transition from object to picture. Because not all cues can be adequately reproduced in 2D, conventions are introduced to compensate for the information loss. To some extent, these conventions are arbitrary and are not always shared by various cultures. Deregowski's Figure 26 nicely illustrates the arbitrariness of perspective convergence; in Western eyes the Oriental style is "wrong." It is fairly obvious that a differential knowledge of these conventions will give rise to substantial performance differences across cultures.

In sum, it appears that an increase in the complexity of a pictorial task is often accompanied by an increase in the number of conventions in the stimulus material. Future research should try to disentangle the effects of complexity and conventions on performance. Whether intergroup differences will remain after a correction for the effect of conventions is an open question. If this reasoning is correct it implies that intergroup differences on perceptual tasks, other than illusions or constancy tasks, should not be accounted for by group differences in perceptual mechanisms.

In the cognitive research of the last decade there has been an increasing awareness of the importance of "metacognitive components" (e.g., Sternberg 1980) such as the repetition of the stimuli in a free-recall task. Analogously, "metaperceptual skills" may be vital to the performance of perceptual tasks (cf. Serpell & Deregowski 1980). For example, the "metaperceptual skill" of knowing that 3D skills have to be applied to 2D pictures is a crucial one. The need to postulate a set of representational skills that have a distinct non-overlap with 3D spatial skills (Figure 25) can be questioned. Occam's razor dictates that rather than postulating the existence of separate 2D skills, the perception of 2D pictures should be viewed as 3D perception complemented by a set of metaskills and knowledge of conventions.

A further step is needed beyond the identification of intergroup differences, namely, the explanation of these differences. At present there is no coherent theoretical framework for the interpretation of such differences in perceptual tasks. Still, it seems quite unlikely that the differences are psychologically deeply rooted. Instead of postulating different skills for various groups, considerations of parsimony suggest that we consider cross-cultural differences as variations on a universal theme.

Perceptions in perspective

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Physiologists may observe that little, if any, note is taken of the possibility that there may be basic anatomical and morphological differences between one "culture" and another (Weale 1982a), and that these may contribute to the effects described by Deregowski. Nor is any reference made to possibly different developmental "sensitive" periods (e.g., Derrington 1978; Maffei & Fiorentini 1976; Mitchell 1979).

Visual acuity for inclined gratings differs in some Mongol eyes from that observed for Caucasian ones (Timney & Muir 1976), and some geometrical illusions vanish in the presence of faulty spherical refraction (Weale 1978). Although Deregowski is clearly aware of how the researcher's conditioning may affect his

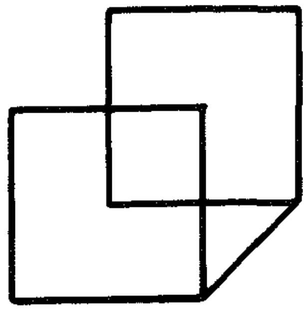

Figure A (Weale). The removal of clues provided by the hierarchy of contours ("overlay") accentuates the ambiguity due to isometry. Rotation through 45° changes an object into an element of a pattern.

interpretation, insufficient allowance seems to me to be made for this. The Japanese use certain syllables in questions and negations that are not translated into English. If we do not use them when speaking Japanese, we are not understood. There are visual parallels to this. Huntsmen see significance in their environment that escapes the sedentary urbanite, yet I wonder whether I should like to have my perceptual virility classified on that basis.

The representation of space is a matter not only of culture but also of convention. Japanese artists of the eighteenth century rendered tables isometrically – a curious compromise, this, between appearance and reality. In pre-Renaissance painting the perspective of a table would be inverted, with the shortest side nearest the viewer: This is how you see a table sequentially as you move past it in either direction. Not even Picasso was novel.

Has sufficient allowance been made for adaptation (e.g., in connection with Figure 2)? Furthermore, eye-movement patterns are not mentioned by Deregowski; the paradoxes of Figure 5 and 6 all but vanish when eye movements are minimised with the visual angle subtended by the Figures greatly reduced (Weale 1982b). I fail to see the rationale of Figure 4: When a pyramid consisting of four triangles is constructed and decapitated, one sees just this: What have I missed?

Some of Deregowski's generalisations relating to illusions are hard to sustain. Several of the examples shown are based on a loss, or withholding, of information, as in Figures 13, 14, and 18. What is crucial to one brain (cf. the above reference to Japanese syntax) may be unimportant in certain contexts to another: Freud or no Freud, I have yet to see a Western rendering of Match-stick Man with the extension shown in Figure 3b.

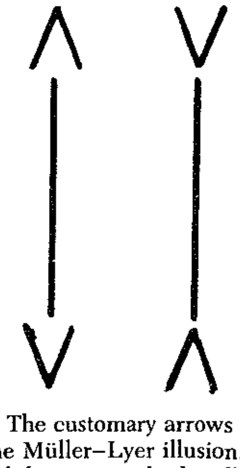

Figure B (Weale). The customary arrows are not essential to the perception of the Müller–Lyer illusion. They merely provide one of several inhibitory stimuli, the efficiency of which can be studied by variations in their composition and their distance from the ends of the parallel lines.

All two-dimensional representation of three-dimensional space – which need not be real – involves some loss of information: Because it is frequently unimportant, such representation is acceptable, which has to be distinguished from being possible (cf. abstract paintings by Tanguy). Figure 6 can be seen three-dimensionally (Weale 1982b) without any elaborate joinery (Gregory 1970). Again, Figure 17 raises several problems potentially relating to culture. In the first place, like Necker's cube and other similar concepts (cf. Gombrich 1962), it is based on the isometric fraud (invented by the Romans, if their mosaics are anything to go by). But the confusion index of Figure 17 can be raised by presenting it in the form shown in Figure A (this commentary) and augmented by a clockwise rotation through an angle of 45°. The Müller–Lyer illusion can similarly be dissected by the removal of contacts between the lines and the inducing elements (Figure B, this commentary).

Much comment is offered on Deregowski's Figure 18; the fact that it causes problems is not surprising, not least because I keep wondering whether the Lord of Creation is left-handed. But I return to painting. The Italians who spend more time in the open air than do the Flemish invented what we call linear perspective. It presupposed immobile eyes. The Northerners glued their eyes to detail, and therefore the early Gothic canvases are renderings of what one sees as one scans one's field of view. You can say that European culture differs from European culture (even in terms of what used to be called International Gothic), but one could be stretching a point.

Finally, the novelty of the percept of Figure 15 is ambiguous: Many like it were painted by Arcimboldi in the sixteenth century (Fernau 1958). I naturally share Deregowski's view that culture conditions. Where I differ slightly is in the belief that its influence can be pinpointed before potential objectively demonstrable factors have been identified.

Cross-cultural research needs cross-fertilisation

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My immediate responses while reading Deregowski's target article were, first, that the cross-cultural literature is mostly very old and, second, that there seems to be almost no attempt to integrate it with more recent research in both the neurophysiological and infant perception literature. Before discussing this research, it is pertinent to consider the problem of response bias.

Although it is true, as shown by the many examples cited by Deregowski, that cultures other than our Western one may respond to pictures in ways that do not appear to indicate direct processing of pictorial information as a representation of real space, there is plenty of evidence even within Western experiments that output or response failures do not necessarily indicate anything about perceptual failures. Given what must be the real difficulty of instructing non-Western subjects as to the task required and the added difficulty of interpreting their responses, I expected to find a rather substantial section of Deregowski's paper devoted to a discussion of these issues. This would have been particularly useful in relation to the studies done in the 1960s when the importance of the distinction between response and sensitivity was underemphasised. Because there is no such discussion, except for a brief one on the difficulty of knowing whether animal and infant subjects' responses to pictures indicate that they take the picture for a real object, respond to the whole representation, or use partial cues, it was difficult to evaluate the extent to which conclusions about differences in, say, shape constancy or illusions, could be accepted as real differences in visual processing.

A particular emphasis is placed on visual illusions in Deregowski's paper and in cross-cultural studies but the exemplars chosen are always those that are alleged by some (e.g., Gregory 1963) to be based on inappropriate use of depth cues. Deregowski's paper virtually assumes the validity of the illusion-through-depth hypothesis. Although many psychologists might agree that inappropriate depth responses play some role in some illusions, very few would accept this model for all illusions. The claim that it has been "demonstrated" that Western subjects experience the Müller–Lyer illusion because the arrowheads influence the apparent depths of the figures is unacceptable. The Pandora's Box experiments show merely that given reduced conditions, these figures can be seen in depth, not that they always are, or that perceived or implied depth is a necessary and sufficient condition for the illusion to occur.

Of most concern is the fact that it has been demonstrated repeatedly (e.g., Yonas et al. 1987) that 5-month-old Western infants are not responsive to the whole range of pictorial depth cues but that 7-month-old infants are. This suggests an inbuilt mechanism. If so, it would be surprising if such mechanisms were not inbuilt in other cultures. Hence, there is an added need to review the cross-cultural literature with problems of response bias in mind. For example, it is difficult to reconcile Yonas's results with Deregowski's claim that Newman (1969) showed that only a quarter of Western six-year-olds perceive depth from texture gradients. Recently, Livingstone and Hubel (1987) have claimed that depth processing of pictorial cues disappears under isoluminant conditions. From this they have inferred that the magnocellular cortical pathway is therefore responsible for such perceived depth and for depth-related illusions such as the Ponzo effect. This also suggests a basic neural mechanism for pictorial depth perception. Finally, Deregowski laments the absence of any data on whether nonhuman primates can generalise with pictures presented at various angles. Surely the work on face recognition which shows that monkeys can generalise over pictures despite changes in various stimulus properties (Ellis 1981), and which reports nuerones in temporal cortex that seem to subserve such functions (Perrett et al. 1985), is relevant.

In short, the use in this paper of the term "perceptual skills" to describe how different cultures respond to pictorial depth cues is too vague; the question needs to be asked whether these skills lie at the input or the output end. At the very least, some cross-fertilisation between cross-cultural and Western infant and neurophysiological research is needed: Although infant research has exploded in the last few years, hardly any of it is mentioned here. Cross-cultural research will continue to be largely disregarded by more traditional experimental psychologists so long as it fails to consider their concerns for experimental rigour and cautious interpretation and so long as it remains an isolated island of research that makes little or no reference to mainstream developments.

Comparative cognition of spatial representation

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Murray Sidman, in his classic book, *Tactics of scientific research: Evaluating experimental data in psychology* (1960), made a convincing case that variance should not be viewed as a nuisance factor stemming from measurement error or as something simply intrinsic to the phenomena being studied. Instead, he argued, variance will sometimes reflect orderliness in underlying causal factors. In this view, which Deregowski seems to share, variance creates the opportunity for further understanding.

Deregowski argues that cross-cultural studies act like a microscope, "By, as it were, 'enlarging' the phenomenon"; in other words, letting us see variability where previously there was only uniformity. What we would like to do in this commentary is to further enlarge the discussion of real and represented space. First we would like to consider cognitive in addition to perceptual processing of spatial information. Second, we would like to describe some recent findings in the animal literature on the cognitive representation of space. In particular, we will describe some research that suggests that some animals encode Euclidean properties of space. We will also discuss some preliminary evidence that different species may represent space in different ways.

The difference between spatial perception and spatial cognition is easily illustrated by two comparable conditions in the widely used Morris water maze task (Morris 1981). In one condition, rats are placed in a swimming pool filled with cool opaque water that contains a small visible platform protruding slightly above the water. In the second condition the platform is invisible, being located just beneath the surface of the water. In both conditions the rat must swim to the platform in order to escape. For rats in the first condition the problem is a perceptual one; for rats in the second condition, the problem is one that requires cognition, in particular the formation of a representation in memory of the location of the hidden platform that had been found during previous swims.

Early research on comparative spatial cognition was concerned primarily with demonstrating that various species were capable of representing aspects of space in memory, with attempts to assess animals' capacity for spatial information, and with studies on the persistence of spatial memory over retention intervals (much of this literature is reviewed in Roberts 1984; Sherry 1984; and Sutherland & Dyck 1984). More recently, interest has shifted to attempts at understanding the nature of animals' representation of space. We have now started to ask questions about the contents of representations, about what aspects of space are encoded in cognitive maps. [See also *BBS* multiple book review of O'Keefe & Nadel: *The hippocampus as a Cognitive Map, BBS* 2(4) 1981.]

Given that animals have evolved in physical space, it seems unlikely that they would have systematically wrong representations of space. On the other hand, it seems plausible that some animals might have weaker or incomplete representations of space. We might, for example, expect quite different representations in sedentary and active species.

The traditional way in which experimenters have attempted to determine which types of spatial information are encoded in an organism's cognitive map has been to use transformational procedures. In these procedures a subject is familiarized to a particular environment and then the environment is systematically manipulated in ways that preserve some spatial aspects while changing others. This approach has yielded some very interesting and informative data.

For example, Van Beusekom (1948) used the transformational approach to examine how digger wasps use remembered landmark locations to find their burrows. While the wasp was on a foraging flight, he manipulated the configuration of pine cone landmarks that surrounded the wasp's burrow. Based on his data, Cheng and Gallistel (1984; see also Cheng 1986) have proposed an interesting mapping strategy in which only a limited subset of Euclidean spatial properties are encoded. In this cognitive map places are represented as lying at the intersection of several straight lines. Each line is assumed to have two distinct points (landmarks) lying on it, which bracket the represented location. By attempting to position itself between the various pairs of landmarks the animal will arrive at a target location. In this type of map metric properties of Euclidean space, such as distance and angular separation, are absent.

Although transformational procedures have proved to be useful they have several problems. First, it is difficult to know in advance which landmarks will be encoded. The experimenter can hope to bias an animal's choice of effective landmarks by the way in which the environment is constructed, but there is no guarantee that the subject will use the "obvious" features. Furthermore, there is no guarantee that all subjects will use the same set of features to construct their representations. It is also difficult to apply transformational manipulations to some spatial cognition paradigms. One of these is the delayed matching of key location procedure (Wilkie & Summers 1982) used to study pigeons' short-term memory for spatial location. During a trail in this task one randomly selected key from a matrix of pecking keys is briefly lit as a sample. After a retention interval, the subject must choose this key when all keys in the matrix are lit. Because of our inability to use transformational manipulations we have attacked the issue of spatial representation of location in this paradigm from a different perspective.

For people educated in the use of topographic maps, extracting distance and angular information is a straightforward exercise. Although mathematically much more complex it is also possible to extract a map from distance information. Several computer programs now exist that use multidimensional scaling (MDS) procedures to perform this task. The classic example of MDS uses airline distances between cities as input and produces a map showing the locations of the different cities (Kruskal & Wish 1978). We (Wilkie 1987; in press) have used MDS procedures to infer the structure of the pigeon's spatial representation of a 2D matrix of pecking keys.

Because psychological distance cannot be measured directly it must be estimated by examining error patterns. Assuming that proximate locations are more easily confused than distal locations, subjects should make more errors at places closer to the target location than those that are further away. By recording key location confusions made by pigeons during retention tests and analyzing these using two-dimensional Euclidean MDS procedures we have inferred that pigeons, like rats but apparently unlike wasps (cf. Cheng & Gallistel 1984), encode metric properties of 2D Euclidean space. More research clearly needs to be done, but it is interesting that there is some suggestion of species differences in spatial representation.

MDS offers an extremely promising new tool for exhuming the structure of spatial representations. We are presently working on ways to extend this methodology to the study of 3D space and of other species' spatial representations.

Author's Response

(Largely) unicultural psychologists in multicultural space

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The commentaries vary greatly in their scope. Some (for example Day's) directly suggest new experiments that could clarify obscurities in the target article; others do so indirectly, by examining the views put forward. Both kinds of commentary are immediately useful. Others touch on much broader issues, concerning themselves with the theoretical foundations of the entire enterprise, as well as with the procedures used to obtain the data. **Jahoda**'s metatheoretical questioning is an outstanding example of this kind of commentary and continues his relentless war against fuzziness of thought and blind obedience to fashion in psychological research, a war whose previous battles are well documented in his earlier writings (Jahoda 1982; 1983).

Several commentators concern themselves with rather specific issues, whereas still others confront more than one of the problem categories described above. In order to deal adequately with such heterogeneous approaches I have decided to present my reply under several headings chosen simply for their convenience.

Theoretical siftings. If one were to wait for a proper theory of picture perception before embarking on cross-cultural work, as **Freeman** appears to advocate, then one would have to wait forever. It seems unrealistic to hope that there will be a time when one will be able to say this is *the* complete theory; all empirical evidence from all the sciences argues against the likelihood of such an outcome. One can and should continue to strive for such a theory, however. In so doing one must examine data, and the greater the range of data one considers, the more general the resulting provisional theory. Providing some of this requisite data is the function of cross-cultural comparisons.

In my view, theories are to be entertained as long as they are useful. This means that if two contrary theories concerning a phenomenon are helpful, both should be taken into account. Hence Bryson's (1983) and Schier's (1986) theories should be the joint framework for discussion, rather than alternatives, as **Freeman** implies. My own inclinations happen to be toward the little-known notions of Chwistek (1924/1960; 1961), who argued that the general cultural climate affects the style of painting as well as of the other arts. He suggested that everything depends on questions such as: "What are things really like?" This leads to what he calls "primitivist reality" or "What do things look like?" This, unlike the preceding question, concerns itself with the relationships between objects and between each object and the painter, and leads to "physicists' reality." A cognate point of view was advanced by Grigg (1984). Such global cultural considerations, however, exceed the scope of the target article.

I cannot agree with **Freeman** that the cross-cultural findings do not call for theoretical explanation because, quite simply, *all* findings do. If they are neglected in one's theorising then not only are they treated as useless curiosa but the resulting theories are bound to be incomplete.

Jahoda makes two metatheoretical points: One concerns the *sameness* of phenomena across cultures and the other the terms *culture* and *cultural*. In addition, he criticises the "fruitfly analogy" as inappropriate because, unlike studies of the fruitfly, cross-cultural studies generally complicate scientific work. The point about the analogy will be considered first, as it is only a minor one. The analogy can be read in two ways: (1) Cross-cultural comparisons (like fruitfly studies) offer a way to do research that could not otherwise be done. (2) Cross-cultural studies offer a shortcut in the investigation of certain phenomena (just as fruitflies do). The former was the intended sense of the analogy in the target article.

Now to the more substantial issues raised by **Jahoda.** It is obvious that my qualifying term "essentially" (sect. 1, para. 2) failed to save the day and therefore the notion of "same phenomena" must be analysed at some length. No psychological processes can be said to be identical unless one makes some arbitrary judgements about the extent of the phenomena and the exact meaning of sameness. Although there are stimuli that are physically the same and there are responses to stimuli that are identical, and sometimes an experimenter even obtains identical responses to identical stimuli from two or more subjects, this does not necessarily mean that the psychological processes of those subjects are identical, a point eloquently made by **Ellis.**

The postulate of sameness that **Jahoda** questions is in my view a commonsense one based on the observation that people from all cultures respond to certain visual stimuli in an identical manner. For example, all people can discriminate distances; they could not survive otherwise. This leads one to assume that the underlying perceptual processes in such cases are to a large extent identical across cultures. The cases in which the same stimuli do *not* produce the same responses must somehow be related to this imperfect commonsense framework, because without it one would be entirely adrift. The need for such a framework becomes apparent at times in the excessive apologies for its absence. This is the second point raised by **Jahoda.** I entirely agree.

Peebles writes that things are much more complicated than the target article implies and that a much broader view should have been taken, notably that various symbolic uses of real space ought to have been considered. Such a broadening, however, could be achieved only at a prohibitive cost in precision (which according to **Eliot** is even now grossly deficient). Consider, for example, the Walbiri illustrations of their tales, to which Peebles refers. Of all the examples he mentions, this is probably closest to the target article's theme: A ring drawn in the sand has, according to Munn (1986), a large number of meanings in Walbiri iconography: It can represent any closed, roughly spherical or circular item or movement, including a nest, a waterhole, an act of circling, and, less obviously, a tree, a hill, an upright fighting stick, or a curled up dog. Each of these representations contains a modicum of 2/3i value but this is so small and so diffuse, and therefore so dependent on the nonpictorial information (i.e., the words of the storyteller) that it is closer to a frozen gesture than to a 2/3i representation. One must (as **Rose** points out) acknowledge the existence of continua, but one must also recognise where these can be profitably divided. For the reasons just stated, Munn's findings and, by implication, the even more remote notions mentioned by **Peebles** were not taken to fall within the scope of the target article.

Biederman may be right that individuals living in nonpictorial or minimally pictorial cultures do not require a special theory of picture perception. On the other hand, a theory of picture perception should be general enough to account for such individuals' behaviour in response to pictures. It is to this end that the distinction between 2/3d and 2/3i pictures was introduced. The former can often be well described in terms of Biederman's (1987) notion of "geons" (simple 2/3d drawings, for example, a cylinder or a cuboid, from which more complex structures can be built). The latter cannot be dealt with in this way, because no such elegant units as geons are available to us. Only about 36 geons will handle all volumetric representations but the number of distinct yet readily recognisable entities of the 2/3i kind is considerably greater: Consider, for example, the variety of outlines (or silhouettes) that can depict a bottle (ranging from a milk bottle to a whisky bottle) or a motor-car (ranging from a 1927 Rolls-Royce to a 1984 Rover). Clearly a process other than the one involved in Biederman's (1987) recognition-by-components (RBC) theory operates here. As the target article suggests, however, both perceptual processes may be open to modification. In the RBC process, the (innate?) geons may be affected by differential environmental exposure. In 2/3i processes, learning may be required to strengthen the basic tendency to see images in 2D patterns that are relatively weaker and more diffuse.

Shouldn't most observers therefore be equally safe and sure in the world of pictures? **Caron-Pargue** thinks not, because perception of the real world may be "wired in," whereas picture perception is not. Yet it seems more likely that percepts corresponding to certain cues of the real world are "wired in" and that when a picture is so arranged as to provide the eye with stimulation similar to that provided by the real world the objects represented will be perceived in a similar manner. Of course the strength of initial "wiring" will probably vary among individuals and groups of subjects, as will the effect of experience that leads to the acquisition of the appropriate skill. The language analogy Caron-Pargue suggests does not seem to be helpful here.

There are inevitable problems with the taxonomy of any phenomena, but I do not find the problem of taxonomic boundaries as important as **Smothergill** seems to. The taxonomies are merely there to provide a convenient framework, not to be taken as either true or false. Zoologists repeatedly reclassify certain animals. This does not prevent them from studying these species; reclassifications are the results of ongoing study. Of course some phenomena do lie on continua, and as **Day** implies, our internal representations of different pictorial cues may vary, and hence boundaries may be vague. Moreover, phenomena may be found on examination to be combinations of factors, each calling for a separate analysis. Such changes in understanding have indeed affected our approach to perception, in both cross-cultural and general psychology. Yet there seems to be a distinctive thread running through the cross-cultural psychology of perception; this is the thread the target article attempted to reveal.

There are ways of classifying pictures other than the one proposed in the target article. One must assess the heuristic value of these rival classifications. Without adopting arbitrary boundaries it is clearly impossible to classify an individual or a group as incapable of perceiving pictures at all or to extrapolate safely from the perception of one picture to another.

These taxonomic complexities support **van de Vijver & Poortinga**'s notion that pictures can be ranked in terms of perceptual difficulty, but there seem to be problems with their concept of decontextualisation. This concept appears to imply that the closer a picture resembles a real object the more likely it is to be correctly identified. The ease with which trompe l'oeil pictures are perceived does indeed support such a view, but when photographs of components of machines and drawings of them are compared as inspection aids, the latter are often superior (Harris & Cheney 1969). Similarly, the ready acceptance by the Me'en of pin figures and the readiness with which the Tallensi (sect. 3, para. 4) drew such figures clearly shows that the elimination of certain perceptual cues does not necessarily make it difficult to perceive pictures correctly. One would not expect highly overlearned 3D skills to be equally helpful in the interpretation of trompe l'oeil and stick-figure drawings; indeed, one would expect their transfer to the latter to be particularly laborious. In view of this evidence, the existence of the single path that, according to van de Vijver & Poortinga, leads from the perception of the 3D world through various pictorial styles seems unlikely. These reservations are further strengthened by the equally strong claims made (e.g., Wyburn et al. 1964) for the optical validity of the Oriental and Western perspectives (see below); and by critical differences between Hudson's drawings (Figure 18) and the Kwengo callipers (Figure 19). The bottom drawing of the latter figure contains information that none of the first three of Hudson's pictures has. It is a 2/3d figure and hence differs radically from Hudson's man, the elephant, the tree, the antelope, as well as the terrain, all of which are 2/3i. The complexities described above must be taken into account by any model of perception, including the ones referred to by **Ellis**, if there is to be an adequate explanation of picture perception in the context of perception in general.

It is almost certain, as **Rose** points out, that the two distinct kinds of representation (2/3d and 2/3i) lie on a continuum because most apparently distinct entities, even cabbages and kings, lie on more than one continuum: This in itself neither commends nor condemns the distinction. The problem is to ensure that the continuum that is identified makes the complexities of perception more comprehensible. This was the aim of the target article, within its very circumscribed field. Of the two continua Rose puts forward, the one involving the behaviour of brain-damaged patients is probably more helpful than the one involving the development of writing. Although studies of brain damage and of natural processes in healthy subjects (on which **Ellis** also comments) are not capable of explaining cross-cultural differences, they may show the extent to which particular perceptual processes are directly dependent on brain structures.

The continuum along which certain scripts developed from pictograms (**Rose**) does not seem helpful in the present context. The changes in these occurred as a result of the scribes' desire to perform their task faster, and hence to simplify the symbols they used. Moreover, there is the puzzle of the pictograms from which the scripts began: Why were they supposedly so elaborate? Why was the shortcut taken by the Tallensi not taken in those early times? How and why was a complex representational code developed instead? These questions go beyond the intended scope of the target article, yet answers are needed if the postulated continuum is to be understandable enough to be helpful.

Both **Day** and **McGurk** have reservations about the "2/3d–2/3i" dichotomy. It is apparent from the target article that 2/3d and 2/3i are the "ideal" types and that they are seldom experienced in their pure form. The distinction nonetheless seems useful. The two grounds on which the distinction is questioned by Day do not appear to have equal merit. The depth cues are indeed subtle, so subtle that a better form than that of the elephant (Figure 3a) should have been chosen to illustrate the point. However, the elephant is still seen as an elephant when its feet are covered; the same applies to the Tallensi figure. It seems undeniable that there are silhouettes that are seen as flat. Day himself provides an excellent figure (Figure 1a) to illustrate this point. Shapes like the elephant have weak 2/3d cues and are therefore likely to be seen by some people as 2/3i. To me, for example, this particular figure is ambiguous 2/3d. It might represent a walking elephant (with the feet that are further away from the viewer lifted) or it could be a sunbathing elephant lying on its side (with the feet that are nearer to the viewer extending into the air). The silhouette was, incidentially, derived from a photograph of a toy elephant laid on its side.

Day's second objection is entirely different in that it does not appear to attack the proposed distinction but maintains that the two kinds of representation are entirely different, the 2/3i representation being cognitive rather than simply perceptual. One can agree with some reservations, for whereas it is true that someone unfamiliar with samovars may fail to recognise a samovar's silhouette or outline it is also true that an unfortunate individual who has never tasted Chivas Regal whisky is still likely to recognise its characteristic bottle's silhouette or outline as a bottle. In other words, perceptual processes are involved in 2/3i representations just as they are involved in one way or another in all cognition.

It would be interesting to perform the experiment suggested by **Day**. The data hitherto published (Deregowski 1971b) offer a weak hint as to the possible outcome. When Figure 17 (of the target article) is rotated 45° clockwise (as **Weale** insightfully recommends), for some observers its appearance changes abruptly and it is seen as flat. The 2/3d element vanishes. In the comparison between Scottish and Zambian schoolboys instructed to build stick and Plasticine models in response to the two figure orientiations, the Scots showed a greater tendency to build 3D models of the unrotated figure; no significant difference between the two orientations was observed in the Zambians. Insofar as the forms proposed by Day are perceptually similar to the ones used in the above experiment (i.e., Day's Figure 1a is symmetrical about a vertical axis just as the rotated Figure 17 is, and his Figure 1b is asymmetrical about this axis, like the unrotated Figure 17) one would expect a result similar to that reported above, with Figure 1a evoking fewer 3D responses. This would accord with Welford's (1970) "principle of economy," which the data collected in the Ivory Coast (Deregowski 1976c) also support. Day's stimuli cunningly incorporate 2/3i cues, however, and this may complicate matters in an interesting and illuminating way.

Similar considerations lead **McGurk** to propose another scheme. This entails a classification of picture depth perception tasks entirely different from the simple dichotomy defined by two ideal kinds of cues: 2/3d and 2/3i. It involves four characteristics that do appear to differ widely. Thus "the amount of transfer to be expected between depth discrimination in three-dimensional space and pictorial depth discrimination" would presumably be affected by the nature of the object(s) represented and the nature of the perceiver. "Accuracy of performance" and "ease of learning" involve the same two elements, but "probability of cross-cultural differences in performance" is such a different variable that it might be inappropriate to treat it together with the others. The three cohesive variables appear to be concerned primarily with the subjects' performance and not (in any detail) with the picture's characteristics. This tends to conflate various pictorial depth cues; the plausibility of **Biederman**'s geons or other 2/3d cues is therefore subsumed in the general measure of effectiveness. Such an approach may provide a useful shortcut in some circumstances, but being nonanalytic it is not likely to contribute much to a theoretical understanding of picture perception.

Downs proposes another representational category, the hybrid 2/3h, which he uses along with 2/3i and 2/3d representations in classifying various map-making devices. His examples of these categories are apt, but one must remember that these representational categories are to some extent subject-dependent: Contours that may seem 2/3h to laymen may seem 2/3d to experienced map users and 2/3i to inexperienced ones. Another probable factor is the required depth of processing. Kinnear and Wood (1987) showed that subjects whose questionnaires about maps forced them to make some use of information depicted by contours remembered the maps better than those whose questionnaires asked for information about the map's references to locations or distances between points rather than using contour information. In another study, Gilhooly et al. (1988) contrasted contour and planimetric maps in relation to expertise in map reading, following up the surprising finding by Thorndyke and Stasz (1980) that there were no differences between experts and novices in remembering planimetric maps. (Planimetric maps represent just the horizontal distribution of features on the ground; there is no attempt to represent the third dimension.) Gilhooly et al. confirmed Thorndyke and Stasz's findings for a planimetric map but not for a contour map, with which skilled map readers clearly had an advantage. All these results suggest that experience, whether it results from the kind of inspection required or from the use of maps, is important. This seems analogous both to findings with tests on cultures that have different experiences with spatial representation and, as Downs points out, to developmental differences within a single culture.

Methodological matters. A question is raised by **Smothergill** about the origins of the shift in cross-cultural perceptual psychology from the early studies of poster comprehension to work on Nigerian students' comprehension of diagrams. This change is more apparent than real. Fussell and Haaland (1978), Jenkins (1978), and Cook (1980) report on the difficulties in picture perception experienced by certain populations. As in the early work, researchers are still primarily interested in the effectiveness of various communication methods rather than in psychological processes. The same can of course be said of some of the work done in schools (Jahoda et al. 1977). Such pragmatic considerations also pervade Nicholson and Seddon's (1977) investigations. One must recognise, however, that studies can only be carried out on the populations that are available, and that the scope of research changes with changes in populations' characteristics (e.g., more widely available schooling or training in certain professions such as radiography or engineering draughtsmanship).

In evaluating historical data one must also be aware of the conditions prevailing at the time the observations were made. For this reason **Hubbard et al.**'s comments on Laws's (see Beach 1901) observations puzzle me: There is no published evidence, as far as I know, that his pictures were in black and white only; nor is there evidence that only minimal instructions were used. It was a common practice in Laws's day to colour black-and-white prints and maps as well as to colour transparancies for magic lanterns such as that used by Livingstone (1857). One would expect Laws, even if his prints were black and white (which they need not have been), to have had them coloured. However, there seems to be no indication in his correspondence whether he used black-and-white or coloured figures, nor any indication as to the amount of instruction given. His remarks in the Student Volunteer Movement (Laws, in Beach 1901) may be taken as suggesting that the instruction was slight. But the style of this report is perhaps deliberately dramatic, as the quotation (sect. 4, para. 5) clearly shows. On the other hand, in a different but related context–reproducing spatial arrangements–Laws refers to "lessons repeated and much annoyance" (sect. 4, para. 2).

Even if one could say that Laws's pupils learned picture recognition easily, such a statement would have as little value as stating that they learned mathematics easily: Not all pictures are equally difficult, as **Hubbard et al.** acknowledge in referring to the Street figures. (This analogy is, incidentally, dangerous, for it is quite common for a person to recognise representations in some Street figures but not in others.) Moreover, pictorial difficulties are of various kinds (they correspond to different skills), and being able to recognise objects, for example, does not necessarily mean that the represented relationships between objects are perceived.

Wenderoth's remarks about response bias should be seen in a similar light. It is difficult to reply to his general remarks about response bias because it is not clear which particular pieces of cross-cultural experimental data he deems invalid because of such a bias. It would have been very helpful if he had identified the relevant studies and given reasons for his view. If his arguments were convincing, one could then eliminate these studies from further consideration. My impression from observing cross-cultural psychologists at work is that they generally take greater trouble and show greater awareness of the impact of cultural values and usages on behaviour (it is after all their *raison d'etre*) than do their culture-bound counterparts. Any examination of experimental reports such as those of the National Institute for Personnel Research in Johannesburg or of the Human Development Research Unit at the University of Zambia for the 1960s, the period about which Wenderoth is concerned, confirms this belief.

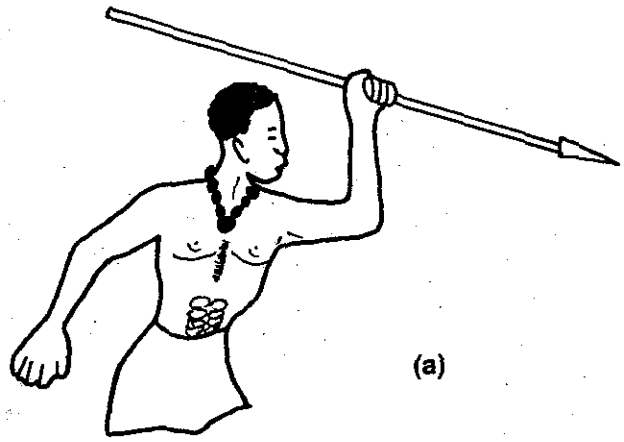
Hudson's test. Hudson's (1960) test, the one that launched systematic studies of cross-cultural differences in picture perception, puzzled some of the commentators. It is not certain that **Piggins** is right in his criticism of Hudson's test on the grounds that the natives do not throw spears at elephants. Pictures can be and often are used to represent things that are not frequently seen, for example, angels (flying winged human beings). Such figures are readily perceived, and if there are enough depth cues, so is the space separating them. We perceive without difficulty pictures of men no larger than a cat engaged in the most unlikely activities, and crowned frogs. There is no reason to believe that an improbable scene in a normally presented picture is perceptually incomprehensible.

Contrary to Chesterton (1929; as cited by **Piggins**) the subjects do see the problem. This is especially apparent when some form of construction task is used, for example, arranging wooden blocks in accordance with a drawing (Dziurawiec & Deregowski 1986b). Subjects often spend considerable time building and rebuilding the model until they are satisfied with the structure. Their comments and actions show clearly that they find the task difficult.

Other comments concern the way Hudson's figures are drawn. The puzzlement with Hudson's drawings is easy to understand. Both **Weale** and **Danto** think that the Hunter is left-handed. I am not entirely convinced of this (here the individual perceptual differences emerge!). He is either right-handed or left-handed. His left leg is forward (his toes show this) and therefore we see the front of his shorts. This suggests strongly that the right arm is used for throwing. The orientation of the torso taken in isolation is admittedly ambiguous and can easily be seen as either facing or not facing the viewer, as shown by slight modifications to the figure (Figure 1 of this Response; Fig. 1a *facing*, Fig. 1b not facing). The hand holding the spear, however, contradicts the extrapolation from his posture, for it is clearly the left hand. This feature of the drawings may seem puzzling to some, but there is no evidence that it puzzled any of the subjects tested on the full version of Hudson's test. Perhaps they simply assumed that the hand used was the one they would have used themselves.

The description of Hudson's pictures in terms of 2/3d and 2/3i cues would obviously differ from observer to observer. It would therefore be inappropriate to claim that any particular description was universally correct; all one can say is that the picture is seen in a particular way by an individual observer or a group of observers, and that a certain way of seeing the picture is characteristic of a certain group. I happen to see these pictures as 2/3i representations of animals and of a man, so arranged and incorporating such additional information that in some of them there is a weak 2/3d effect. This is shown by Deregowski and Byth (1970) using Gregory's (1968) Pandora's box: Distances of various figures within pictures were judged using binocular vision while the pictures were viewed monocularly. In the figure in which the 2/3d was recorded the elephant was judged to be further away from the observer than either the hunter or the antelope.

McGurk's comment that there is no possible space to which Hudson's pictures could correspond can only be true if all the ways in which a picture can represent space


(a)

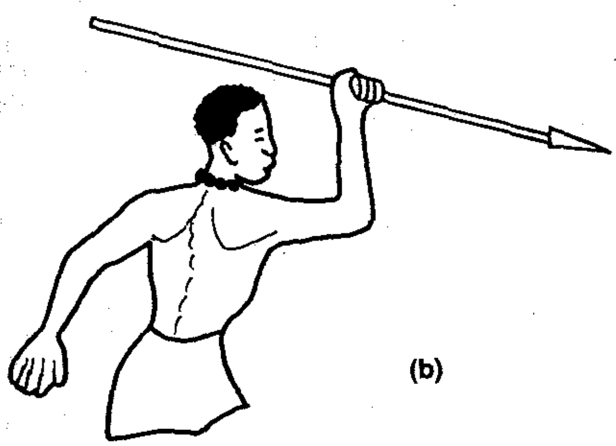

(b)

Figure 1 (Deregowski). Modifications of the original drawing of the hunter showing how his apparent handedness can be influenced by an appropriate drawing of his torso. (a) Facing; (b) not facing.

were shown to be violated by these pictures. This is not demonstrated by McGurk and is clearly contradicted by the Pandora's box finding (Deregowski & Byth 1970) that Scottish observers do not see the figures in some of these pictures as coplanar.

Perceptual skills. The "defects" in stimulus presentation that have been pointed out by the commentators are only important if they affect subjects' responses to the crucial question of whether they *see* depth in the pictures. There is no evidence that they do. The eye, unless it is specially trained, readily accepts all kinds of approximations to the information that could be derived from the real world. There is no *true* picture in the way there is a *true* colour, as **Indow** points out. His contrast between the cross-cultural differences associated with the linguistic partitioning of the colour spectrum and the problems of picture perception is very revealing (see Harnad 1987). It underscores the essential differences between the processes involved. Linguistic partitioning of the colour continuum is not a matter of perceptual skill but of taxonomy. When such a taxonomy is not sufficiently precise, further subdivisions can still be made by using periphrasis. In certain Bantu languages, for example, the same term is used for green and blue, and this normally sufficies; but when the need for greater precision arises one simply says "green of the trees" or "green of the sky." In contrast, a speaker may know the colour terms and not know how to distinguish the colours; one may know that in Polish two terms for "grey," *szary* and *popielaty*, are commonly used, but not which shades of grey each refers to. The linguistic labels approximately describe subjects' experience of colour. In this experience certain colours are perceptually focal and their focality is independent of social values. Thus, Turton (1980) reports that the Mursi of Ethiopia, whose entire social life is centered on cattle, describe reddish-brown cows as being *golonyi*. They also use this term to describe other reddish-brown objects, but they regard these descriptions as approximate. When shown a highly saturated red stimulus they are likely to describe it as *goloin-tul* (truly *golonyi*), although it is unlikely that they have seen the colour before and the colour is not associated with the cattle.

Perception of pictures is likewise not affected by language. The similarity between colour perception and picture perception ends here. Pictures are by their very nature ambiguous because the same picture can generally be matched to a number of objects. Colours are not ambiguous. A colour may be difficult to describe and may therefore elicit a number of descriptions but it is easy to match perceptually. Furthermore, whereas there is a colour that is seen as the typical red (or *goloin-tul*) that represents all reddish colours, there is no picture that represents, say, all men. The variety of men is not easily encompassed; the task can only be attempted by using a 2/3i figure such as a pin-man. Such a picture does not look like any man, however. It does not represent men in the same way that "goloin-tul" represents reddish colours. In short, picture processing is markedly more complex.

Indow argues that the essence of a represented object's recognition lies in the mathematical notion of *similarity*. This may be right, provided that no mathematical precision is implied. Precision is not necessary because the eye is very tolerant and will happily treat imperfect information as if it were perfect. This attribute is essential for the survival of the species; it is also responsible for the acceptance of less than perfectly similar images–the taproot of art. Consider the picture illustrating **Freeman**'s commentary. It is seen by most people as a satisfactory depiction of a receding road. It is not correct, however, as far as human vision is concerned, because the converging lines of the picture, if extended, intersect at one point, and as Bartel (1958) and ten Doesschate (1964) have demonstrated, this is not how we see parallel receding lines in the real world. The single point of convergence merely approximates closely enough to the real-world experience to create 2/3d pictures. Analogously, the pin-man does not look like a man but is sufficiently similar to constitute a 2/3i picture.

A caveat should perhaps be added here about **Thro**'s assumption that "Renaissance geometrical perspective" offers a "standard of fidelity." This standard, it has been shown, is not particularly good (ten Doesschate 1964); nor is it equally applicable under all conditions, as "inverted" (divergent) perspective considerations imply (Deregowski 1984; 1988; Wyburn et al. 1964; Zajac 1961). Nor is it incorrect (as **Halpern** seems to think) to regard engineering drawings that lack perspective as essentially abstract, arbitrary symbols. The objects represented in such drawings are drawn in a variety of projections, but these do not differ greatly, if at all, from those used by artists. The dominant projection (called orthographic) corresponds to the view of an object from an eye placed at infinity, a view often found in works of art. Conventions used by engineering draughtsmen in depicting objects are few. Most pertain to ways of dimensioning drawings and indicating manufacturing processes, machine precision, the nature of the material, and so forth. Incorporating these conventions does not alter the appearance of the drawing in a way that would affect its perception greatly, yet the available evidence (Deregowski 1980a; Dziurawiec & Deregowski (1986a) suggests that it is perceptual skills that differ between populations. Indeed, if such drawings were based largely on arbitrary engineering conventions, these would generally be equally unfamiliar to all students; hence students of all cultures would be expected to do equally well in examinations in engineering drawing, with the better students, of whatever origin, better at drawings too. Both these expectations are contradicted by the available data (Deregowski 1980a).

Halpern's analogy between the ability to read drawings and the ability to read English is thus clearly opposed to the notion of the importance of conventions, a notion that she also embraces. This notion, as we have shown, cannot be sustained. Is the analogy to skills in English helpful? It does not seem to clarify the cultural differences in perception of spatial representations by first-year engineering students; there is no evidence that the students who perform better at engineering drawing do so because they have had training in the relevant skills before entering the course.

Perceptual processes do vary within a culture. As Thomas (1962) has shown, trained industrial inspectors do not see metal castings in the way they saw them before training. Moreover, before they were trained they found it very difficult to see the metal castings the way they saw them after training. As the physical stimulus in question remains unchanged, and yet the outcome is entirely different, the perceptual process must have changed in the course of training. Inspectors are therefore a very special subpopulation. We also know that not all applicants for the inspector's job are equally trainable and that not all inspectors perform equally well. It may be true that all sighted people have some modicum of an inspector's skill and that training has merely developed it, just as, according to the carpentered world hypothesis (Segall et al. 1966), exposure to carpentered objects affects skill in judging line length in the Müller–Lyer figure. Perceptual processes therefore do vary, both within and between populations; but the variations within appear to be less than the variations between; and one of the purposes of cross-cultural psychology is to discover the extent of such variations within the human species in order to describe and understand the visual phenomena better.

There are studies of training – or, as **Biederman** would have it, of exposure and feedback – that suggest the relevant skills can be acquired, although doing so is not a simple matter. The earliest report is that of Laws (see Beach 1901). Forge (1970) had trained some Abelam by using concentrated scrutiny of photographs and discussion to identify the people portrayed. The training he reports took a few hours. Other studies, such as those of Ferenczi (1966), Serpell and Deregowski (1972), Deregowski (1974b), Leach (1975) and other workers reviewed in Deregowski (1980a) as well as the more recent studies of schoolchildren and students by Seddon and his associates (Seddon, Einaiyeju & Jusho 1984; Seddon, Tariq & Dos Santos Veiga 1984), report a large variety of training methods. None of these seems to offer an instant and universal panacea for picture perception difficulties. The studies are not comprehensive. The most startling defect many of them share is that the effects of training are measured on the same kind of stimuli as those used in training. Hence they can at best be regarded as measuring performance on one kind of picture and not improvements in pictorial perception in general. (For a discussion of recent developments in training methods applied to technical drawings, see Rabardel and Weill-Fassina 1987.)

Two points need to be stressed in connection with **Ellis**'s and **van de Vijver & Poortinga**'s comments on the notion of skills put forward in the target article and the nature of the abilities involved in pictorial perception: (1) It is possible (as Figure 25 shows) to acquire some skills relevant to picture perception without ever seeing a picture; (2) pictures vary; different pictures call for different perceptual skills. It is hence possible to generate a picture that is correctly perceived even by people who have had no pictorial experience, just as it is possible to make pictures that even people with considerable visual experience find difficult to perceive. It is also well documented that there are changes with age in the susceptibility to illusions that inhere as elements of some pictures (Coren & Girgus 1978; Robinson 1972, ch. 4; Segall et al. 1966; Vurpillot 1963); also, pictures are not equally well perceived by observers of different ages even in a very pictorial culture (Elkind 1969).

The target article refers to region E of Figure 25 as representing perceptual skills *"insofar as representation of space is concerned."* This is an important qualification and should not be overlooked. Area E does not represent *all* the skills that can be derived from the experience of the real world but only those concerned with direct perception of pictorial depth. Hence a simple dichotomy between skills that do and do not overlap with the external world is not conveyed by the figure. Nor is it suggested that there is *no* similarity between the pin figure of a man and a real man, as **Rose** implies. A similarity must clearly exist–otherwise how could recognition take place? But this kind of similarity is not the same as 2/3d similarity.

The number of 2/3d elements needed to convey the 3D nature of a represented object unambiguously and the extent to which their effectiveness depends on the pictorial sophistication of the viewer are matters for empirical investigation. The less sophisticated among the children investigated by Young and Deregowski (1981) showed less of a tendency to integrate the elements conveying pictorial depth. In **Kennedy**'s terms, they did so because they had not acquired the principles of organisation; as suggested by Serpell and Deregowski (1980) and the target article, they did not have the necessary pictorial skills.

It would be wrong to consider that these skills are only the ones concerned with perception of spatial representations (2/3d); other more subtle skills are certainly involved too. One cluster of such skills, affecting 2/3d as well as 2/3i perception, is probably the one involved in the use of metaphors (Cresswell 1983; Kennedy 1982). Kennedy points out that certain pictorial metaphors are readily understood by the blind as well as the sighted. Blurring the representation to convey movement is readily accepted by the latter; the congenitally blind draw a jumble of spokes when drawing a wheel in motion. Such metaphors are likely to be universal. Certain metaphors, however, do not seem to have such universal validity. "Speed lines" are in this category, as Duncan et al. (1973) have observed. Another nonuniversal cue is the drawing of a many-faced man which is seen as a deity by Indian children but as a king shaking his head in disapproval by Aberdonian children (Deregowski 1984). Analogously, one suspects that Indian children would see Kennedy's many-armed housewife (Kennedy 1982, Figure 3) as a proper representation of a goddess of domestic order.

Some of the relevant skills are concerned with understanding the relationship between real and represented space. This calls for a definition: For the purpose of the target article, "real space" is an entity that has three mutually orthogonal linear dimensions. It is homogeneous and isotropic. It may be empty or filled. When empty it is not visible and therefore cannot be represented. When filled with visible objects it can be seen and represented in pictures. By definition, 2/3d figures are elements of *represented space,* and arrangements of 2/3d and 2/3i figures *create represented* space. Because the notion of *time* is not included in this definition, it is plain that the target article is not concerned with transformations that occur whenever there is a relative movement between an observer and another object, or with mental encoding of such transformations. A discussion of **Eliot**'s difficulties with driving is therefore not called for. Experiences with this space are important, however. **Danto** seems mistaken in saying that differences in picture perception cannot be accounted for by different experiences of real space. Segall, Campbell, and Herskovits's (1966) and Berry's (1971a, 1971b) data argue against such an assertion as far as 2/3d cues are concerned. This is not to deny that experience with pictures is important for the acquisition of picture perception skills, but such experience is not the only influence.

The experience of space is, as **Piggins** implies, not independent of the experience of time, because it is ultimately involved with spatial experience; this should make the project described in the target article all the more interesting to cognitive psychologists. There seem to be two ways that time could impinge on cross-cultural research on space perception: One involves the mental manipulation of real or represented objects and the other the representation of objects in motion. The first phenomenon has long been implicitly incorporated in several spatial tests used cross-culturally (e.g., the Blox test of the National Institute for Personnel Research of Johannesburg) and in Piagetian studies of spatial perception (Dasen 1974) but it does not seem to have been thoroughly explored cross-culturally along the lines laid down by Shepard and Metzler (1971). The second phenomenon has attracted even less attention: Duncan et al. (1973) and Winter (1963) were concerned with the perception of represented movement and found that "speed lines" and multiple images were not universally accepted. This raises an interesting point. To what extent should inaccessible populations be credited with such a convention? For example, should we accept that the Palaeolithic engraving containing multiple outlines of an animal represents this animal in motion?

Hirtle is right that unicultural research complements multicultural research. It is well established that spatial arrangements in either real or imagined space can serve as memory aids. Mnemonic aids exploiting this fact have been in use since medieval times. Cole and Scribner (1974) describe a cross-cultural study showing great improvement in recall when the Kpelle were required to memorise a series of spatially dispersed objects. Kearins's (1981) data (that **Hirtle** mentions) confirm this. Nadel (1937a; 1937b; 1937c) tested two Nigerian populations, the Nupe and the Yoruba, on the recall of pictorial material. These people lived in similar environments but their cultures differed greatly. They spoke different (though related) languages and differed grossly in their cultural characteristics in spite of the superficial similarity of their economic and political lifestyles. The differences lay primarily in those aspects of culture that Nadel expected to be reflected clearly in psychological attributes. The Yoruba religion was elaborate and had a rationalised system of deities. The Nupe religion had no such system; they believed in magic and impersonal power. Yoruba art was rich in religious symbolism; mythical emblems were important. In contrast, Nupe art was imageless; they had only crude wall-paintings and a relatively rich, purely ornamental, decorative art. Nadel used two recall tasks, one with stories and the other with pictures. In the story study the two groups were found to differ in their attitude to logical coherence. The Yoruba tended to adhere to it, and indeed to strengthen it by inventing new logical links; not so the Nupe, who tended to list items and events. When recalling pictures the Nupe were more sensitive than the Yoruba to temporal arrangements and stressed unity of solution and emotional tone rather than rational consistency. They were also found to make their responses very frequently in spatial terms, using such categories as top and bottom, left and right, front and back.

The cultural differences between the Nupe and the Yoruba are similar to those that Chwistek (1924/1960; 1961) and Grigg (1984) consider. Their work suggests that there might be important cross-cultural differences in the treatment of 2/3i and 2/3d pictures. Thus one would expect the Nupe, who were more inclined to use spatial concepts, to also tend to seek out weak 2/3d cues and build their spatial descriptions of pictures around these, whereas the Yoruba would be expected to dismiss such cues in favour of a more rational unifying story–a better tale. Although such a comparison would be of great interest, particularly for the "grand" theories of art development, it does not appear to have been carried out.

Drawings, especially children's drawings, offer a key to picture perception according to **Caron-Pargue** and **Freeman,** who both find the target article incomplete because it lacks studies of picture production. Unfortunately, systematic cross-cultural studies of drawings are very few, and it is not clear that they would have been illuminating. Freeman (1980) and Caron-Pargue (1987a) have repeatedly shown that Western children systematically modify their drawing skills as they develop. Data obtained by Bartel (1958; see Deregowski, 1986, for an English summary) show that illiterate European adults produce drawings similar to those of young children who have scarcely been schooled. There are similar, though rather sparse, data from other cultures (Deregowski 1980a, ch. 5; Deregowski 1984, *passim*). There is also evidence (Deregowski 1976b) from studies of Bukusu schoolboys suggesting that drawings of a model cube, whether done with the model present or from memory, resemble drawings from memory of an isometric cube drawing. Presumably, therefore, these drawings reflect the same difficulties. When drawings are made with the isometric drawing on display, however, these difficulties disappear. This suggests that it is not the general drawing skill that is lacking but rather the more specific skill of projecting a 3D object onto a plane; and, of particular import here, this skill lags well behind the ability to perceive three dimensionality in a drawing of a cube. Hence there appears to be a degree of independence of perceptual skills from drawing skills. This is perhaps not surprising; the visual perception of normal observers is such that they are quite capable of accident-free movement in the real world, which only a few of them can draw.

There seem to be serious obstacles to explaining children's perceptual processes by analysing their drawings. Consider Tale drawings of men (Figure 3b). These figures lack any facial features and have other features (the navel, for example) of rather exaggerated size. This seems not only to suggest that the draughtsmen lacked drawing skill, but, more important, that what they were attempting to draw falls outside the realm of canonical figures (Davis 1985; Hochberg 1972) and can be considered caricature. This claim is sustained by drawings of geometric solids; for example, an eight-year-old girl drew a nineteen-pointed star to represent a six-sided pyramid standing on a cylinder (Werner 1948, p. 120). It could perhaps be argued that responses on construction tasks in which each face of the represented cube is reproduced with an entire cube (Deregowski & Dziurawiec 1987) are similar to those just cited. This seems intuitively unlikely; a subject is more likely to make multiple representations of single elements when faced with the task of compressing three dimensions into two than when asked to expand from two into three dimensions. This essential difference inclines one to regard the research on children's drawing as only marginally relevant to the problems of perception.

Although the target article is primarily concerned with studies using stimuli that **Freeman** describes as deliberately meagre, this does not mean that pictorially richer stimuli have been completely neglected by cross-cultural psychologists; they have simply not been used in studies concerned with percepetual processes. However, such stimuli have been widely used in research on pictures as means of communication in a broader social setting (Goldsmith 1984); such a study (Hudson 1967), in fact, drew Hudson's attention to the complexities of picture perception.

The reasons that prompted Hudson and others after him to use rather simple stimuli are in part the same as those that prompt numerous students of children's drawings to request that their subjects draw a cube and not, say, a dodecahedron–a desire to purify various putative causes of the difficulty. Furthermore, it seemed likely that such meagre stimuli would accentuate the difficulties and therefore provide a more effective way of investigating the problem. The rationale, in short, was that because the difficulties investigated are *pictorial* they must be investigated on material that is clearly pictorial.

Developmental issues. Several commentators draw my attention to developmental observations of rather narrowly defined groups. Developmental studies, like studies on people with certain kinds of brain injuries and studies on animals, present many tempting analogies and many problems.

The infant perception studies of Yonas and his associates (e.g., Granrud et al. 1985; Yonas et al. 1978) do show that infants respond to certain depth cues in a very decisive manner. They try to reach more often for objects drawn to appear closer than for those that appear further away. A single 2/3d pictorial depth cue presented in a very strong form appears to be efficacious. The target article (sect. 8, para. 8) postulates that an analogous factor might account for the results obtained with the Construction Task and with Jahoda and McGurk's (1974 b; 1974 c) stimuli. None of these results, however, can demonstrate that the subjects who make such responses perceive depth in ordinary pictures. They merely show that it is possible to refine and strengthen a 2/3d pictorial cue to the extent that it is mistaken for the real object; in short, one can create a trompe l'oeil picture. It would indeed be surprising if this were not so. Available evidence also suggests that given sufficiently explicit cues, young children in relatively less pictorial cultures respond readily to pictures (Jahoda et al. 1977; Perkins & Deregowski 1982). Most pictures are not of this kind, however; in some of them, depth cues are very diluted, and in some (those seen as 2/3i) they do not appear at all. Moreover, the questions that reveal difficulties in picture perception are not of the kind: "Is there something there?" (which was the kind of question that Yonas's grasping infant was answering), nor even "What is there?" (which was the question that all of Hudson's (1960) subjects had to answer correctly in order to be allowed to continue with the experiment), but much more subtle questions about spatial relations within the picture.

Other developmental studies have shown that similar mechanisms may be involved in the case of **Down's** distinction between the holistic "stand-for" and the componential "stand-for" relationships. Downs considers these in relation to the perception of maps. This particularly interesting topic has not been widely studied in the cross-cultural context, although there are unpublished reports suggesting that students from some of those populations that find engineering drawings difficult also find it difficult to extract certain information from maps. This difficulty is particularly acute when geological maps are used and students are required to draw sections showing stratification.

Wilkie & Willson enlarge the scope of the discussion by bringing in studies of animal cognition of real space. The problem of the perception of real space does not appear to have been studied extensively in cross-cultural settings; this is partly, one suspects, because of the great complexity of the procedures used by men in finding their way about, as descriptions of hunting and nomadic peoples show (see Gladwin 1970; Marks 1976). It is therefore difficult to find close parallels between the aspects of perception considered in the target article and the studies of animals' cognitive maps. Some communalities no doubt exist, but these are as yet too ill defined and too little explored to serve as a basis for discussion.

The effect of maturation on picture perception is complex. Deregowski (1968a) shows that familiarity with the represented object facilitates matching between the picture and the model and that the handicap of unfamiliarity is more severe in the case of adults than in the case of children–an important difference (in view of the claims for the influence of maturation on picture perception advanced by **Hubbard et al.**) and one that is concordant with differences found on other pictorial tasks (Deregowski 1968b).

Physiological factors. Two of the commentators (**Coren** and **Smothergill**) think that genetic aspects of the problem should have been more fully explored in the target article. The remark made in the target article and noted by Smothergill about the lack of data to evaluate genetic aspects of picture perception ought to be read as applying to all cross-cultural data hitherto gathered. This gap results in part from an attempt to make cross-cultural studies relevant to the populations involved, implying that the interests of teachers and factory managers take precedence over those of geneticists and psychologists. The latter two groups could of course benefit from the change of emphasis in cross-cultural studies, which should ideally cater to all academic interests, even if such studies are as rare as the light-eyed Negroes (Tsafrir 1974). The current literature (for a review, see Coren & Girgus 1978, pp. 114–15, also Timney & Muir 1976) suggests that genetic effects might influence some illusions and hence presumably some of **Biederman**'s (1987) geons. This would suggest that there is genetic influence on 2/3d cues. And if **Day**'s suggestion is correct that 2/3i cues are acquired through experience, the genetic differences would presumably determine the acquisition rate of such cues. These statements are no more than hypotheses, however. The possibility that between group genetic differences may in some measure account for the cross-cultural variation is acknowledged in the target article (sect. 12, para. 1), but genetic influences do not negate the notion of differential skills; and studying them, as **Jahoda**'s commentary shows, may not be easy.

The characteristics of the eye and other genetically determined attributes may, as **Coren** points out, affect the perception of certain illusions and may confound cross-cultural findings. These points are well taken but, unfortunately, the pertinent data are not entirely convincing. The effect of iris pigmentation, as Coren and Porac's (1978) data show, is significant but small. In the case of Müller–Lyer illusions, their light-eyed subjects experienced an illusion of about 7.5% and their dark-eyed subjects an illusion of about 6.4%. The discrepancy of 1.1% is very small indeed compared with the between-population discrepancy reported by Segall et al. (1966, Figure 11); for the same figure, albeit under different experimental conditions, this was 18% (between Bushmen and Evanstonians). Furthermore, Coren neglects to consider two important papers by Jahoda (1971; 1975). In the first, no significant difference was found between Malawian and Scottish subjects in their responses to either blue or red versions of Müller–Lyer's figure. Pollack and Silvar's (1967a; 1967b) and Silvar and Pollack's (1967) results suggest that whereas there should be no difference in the case of the red figure, the blue figure should evoke a weaker illusion in Africans. The performance within the African group (i.e., with the pigmentation held constant) was affected by colours, however: Africans experienced less illusion when presented with red Müller-Lyer stimuli and identified geographic profiles less accurately when these were purple/blue than when they were yellow/red. As an extension of this work, Jahoda (1975) compared Ghanaian and Scottish subjects on matching shapes presented in either red or blue. There was no difference between the two groups with blue and red stimuli, contrary to the hypothesis that Ghanaians should find the blue stimuli relatively more difficult. Such findings suggest that the pigmentation hypothesis, although attractive, may not be able to account for much of the cross-cultural variance. Its attractiveness, it might be noted *passim*, is thought by M. M. Kurdelebele (private communication) to lie in its obvious superficiality of locus. It does not postulate that the phenomena in question are central; it hence sustains the notion that such between-group differences as may be found are essentially skin (or fundus oculi) deep. This point of view, however, is difficult to reconcile with the observation that some illusions (including Müller–Lyer) are still experienced when their essential elements are presented separately to the two eyes (Julesz 1971; Schiller & Weiner 1962).

It is also difficult to accept **Coren**'s assertion that Segall et al.'s (1966) population samples were all more deeply pigmented than the Europeans, for it included Evanstonians, Northwestern University students, and South African Europeans. It also contained Bushmen, who are peach-coloured and therefore on the pigmentation hypothesis fall between the "Europeans" and the clearly darker populations such as the Bete and the Zulu. However, Segall et al. report that the Bushmen experience the Müller–Lyer illusion less strongly than all but one of the "black" groups tested and are therefore nearly at the bottom of the continuum whose other end is occupied by the "European" groups. On the other hand, the groups' rank order on susceptibility to this illusion agrees on the whole with the carpentered world hypothesis. Thus, Jahoda's (1966) finding of no effect of carpenteredness can be contrasted with that of Segall et al. and others (e.g., Gregor & McPherson 1965), who round some, seldom wholehearted, support for the carpentered world hypothesis. The problem is no doubt complicated by the difficulties of cross-cultural sample matching because there are no cultures where selective migration and therefore selective exposure to carpenteredness does not occur. Such a migration may be linked to other psychological factors such as Witkin's field dependence (Berry 1968).

Less specific physiological factors are put forward by **Biederman**. It is hard to accept his suggestion that the difficulties observed in certain groups are simply due to visual defects. The picture used with the Me'en that Biederman thinks was *small* was, in fact, 45cm × 95cm (3'2" × 1'9") in size, and the pictures of the three "small" objects measured as follows: the *elephant*, 7.5cm at the shoulder; the *tree*, 13.5cm tall; and the *spear*, 38cm long. These are hence relatively large compared with the photographs used in other studies (Cole & Scribner 1974; Deregowski 1968a; 1971a; Doob 1961; Forge 1970). Forge's (1970) process of outlining, which led to the recognition of the features, might indeed have had the effect of overcoming a visual defect, but it seems more likely that it served the same purpose as outlining an animal figure with a finger in the case of the Me'en The decline in accuracy of identification reported by Kennedy and Ross (1975) parallels the decline in the tendency to see geometric figures as having 3D structures, as reported by Deregowski (1968a); there is no reason to think that declining acuity would lead to 2D rather than 3D perception. The problem may hence be more complex, as is also suggested by the observation that the Abelam had no difficulty recognising photographs of their relatives when they were portrayed standing rigidly at attention against a uniform background but had great difficulty when the photographs showed them in various workday postures (Forge 1970). Further evidence against the visual defect hypothesis is provided by the fact that: (1) Perceptual difficulties increase with stimulus complexity in tasks such as reproducing arrays of cubes (Dziurawiec & Deregowski 1986a) and (2) the adult subjects tested in non-Western samples tend to be relatively young because these populations are relatively "young" in relation to Western populations.

Weale criticises the target article for not discussing sensitive periods or possible ethnic differences in anatomy or morphology. There isn't a large enough body of data to allow us to relate the cross-cultural studies of perception with studies of these aspects of the eye. There are, for example, significant differences in lens thickness between the Bantu and Danes (Clemmesen & Luntz 1976) as well as in other eye characteristics (see Weale 1982a, ch. 10), but their relevence to the perception of real and represented space has hardly been investigated. This problem is even apparent in the references cited by Weale concerning sensitive periods. Two of these studies concern kittens and the relationship between astigmatism and neural development. Although these findings *may* be relevant, it would be difficult to show their immediate relevance to the data examined. The same is true of eye movement and the influence of the angle a picture subtends at the eye. The latter clearly matters, as Weale (1968) has shown, and its effect may vary cross-culturally, but this has not, as far as I know, been studied.

It is not clear why **Pollack** thinks a decrease in illusion susceptibility with age argues against the carpentered world hypothesis. It might if there were evidence that there are no other factors, like those suggested by Segall et al. 1966, which affect the illusion. Such factors may be present, however; they could either take the form of a physical change (such as the changes in the eye demonstrated by Pollack) or they might result from adaptations that counteract such an experience (for example, increased awareness of the flatness of pictures as a result of exposure to picture books).

The "oblique effect" is also a rather elusive phenomenon. Annis and Frost (1973) have, as **Piggins** reports, compared Western subjects and Cree Indians and found that visual acuity anisotropies of the two groups were consistent with differences between the environments in which they lived. The implications of this finding are weakened, however, by Timney and Muir's (1976) finding cited by **Weale,** that there were significant differences in anisotropy between Western and Chinese subjects living in the same environment. The only conclusion one can draw is that perhaps the same effects can occur through experience or genetic endowment.

The finding of specific neural pathways and structures in picture perception (noted by **Wenderoth**) is very interesting and promising, but what has hitherto been reported does not explain cross-cultural differences, or even individual differences. The findings tell us something about the neural networks involved, but nothing about why different observers see the same stimuli differently. I am grateful to Wenderoth for bringing to my attention Ellis's (1981) work and its possible relevance to the consideration of the angle of view in animal experiments. Unfortunately, in none of the data reviewed by Ellis was the angle effect explored; nor has Perrett (personal communication) investigated it.

The rediscovery of the discovered. There is a fundamental disagreement between the basic theme of the target article and **Pollack**'s and **Weale**'s views of representation. This is apparent from Pollack's statement that pictorial space had to be continually *reinvented* in the history of Western art. My view is that it is more likely that the *techniques for creating* such a space were continually being *rediscovered,* although even this term is inaccurate insofar as it erroneously implies that there were periods in which such techniques were entirely unknown. A precise description would probably be that the techniques for spatial representation were continually modified, as were the techniques for representing other characteristics of the world. All these techniques, however, relied on the *discovery,* either deliberate or accidental, that certain patterns can evoke percepts similar to those evoked by certain objects. This was so from the beginning of art. In the words of **Kennedy** (1975), drawings were discovered and not invented.

Picasso's work was not, as **Weale** points out, novel. This applies not only to his paintings of the table, but also to his paintings of faces, which consisted of combinations of frontal and profile views. Such paintings seem to have been all the rage in the Spanish monasteries of the eleventh century, where this style was used with gay abandon to portray saints and apocalyptic beasts just as Picasso used it to portray his lovers and his cats (Deregowski 1984). Romans, according to **Weale,** were the fraudulent crowd that *invented* isometric projection. At this point Weale and I part company, not because I have any strong opinions about Roman virtues but because I think that theirs was not an *invention* but a *discovery.* When they did it, one day in the forum, they had an "Aha!" experience, discovering a new trick their eyes could play on them. A similar experience must have been enjoyed much later by those artists who discovered and incorporated Mach bands in their work (Weale 1979). There is no reason to assume that the eyes of other people will not play a similar trick on them – hence the use of isometric figures in cross-cultural work. In the same spirit, Arcimboldi-like designs are used in both cross-cultural studies and general perceptual investigations (e.g., Elkind et al. 1964).

The discovery of pictures was the discovery of special objects with a dual nature, a concept on which **Danto** comments. This duality is *perceptual,* that is, an observer sees a picture as an *object* (which has certain physical properties) and also as a *representation* (which has different physical properties). The duality is generally accepted, as is the duality of statues, which can also be described in these terms. Pictures are more interesting to a student of perception, however, because they represent a blend of 2D and 3D cues. In addition, the dual aspects of pictures are distinct in terms of these cues yet interact in forming a percept (Pirenne 1970; Polanyi 1970). As Danto points out, these cues may assume an entirely different importance when considered by an art critic.

Illusions. The acceptance of illusions as pictorial elements is called into question by **Kennedy** and by **Pollack.** It is difficult to agree with Kennedy that it might be a gross error to regard illusions as basically pictorial, because this claim applies to all illusions, a notoriously heterogeneous population, as various factor analytic studies show (Coren & Girgus 1978, ch. 13; Deregowski 1980a, ch. 2; Jahoda & Stacey 1970; Taylor 1974; 1976). Some illusions, at least, appear to be an essential element of pictures, as Gregory (1973) has demonstrated and as Jerison's (1967) and Deregowski and Parker's (1988) studies of apparent changes in figures seen by a moving observer show. The same configuration of lines, it seems, when not part of a recognisable representation of an object, is called an illusion; when it represents an object, however, even an entirely unknown object (as Biederman, 1987, and studies of the impossible figures show), it constitutes an essential element of a picture.

Sometimes illusions take a complex form in pictures. Both the absence of a Ponzo effect in the comparisons between Pennsylvanian and Guamese students carried out by Leibowitz et al. (1969) and the weak between-population differences reported by Segall et al. (1966) on their *perspective* figure (which may be thought of as a version of the Ponzo figure) must be considered in the light of other results reported by the Leibowitz group. These show a steadily increasing disparity between the Guamese and the Pennsylvanian subjects; the experimental conditions can accordingly be ranked in the following order: (1) illusion figure on its own, (2) density gradient (a photograph of a receding textured plane) on its own, (3) density gradient with illusion figure. The difference in the second condition is about 0.6 of that in the third condition. Hence, although the illusion does not appear to discriminate between the two populations when presented on its own, it acts as a potent catalyst, clearly enhancing the gradient effect. Such a "catalytic" action does not detract from the importance of this illusion figure as a component in pictures; on the contrary, it demonstrates its importance. The Müller–Lyer illusion is also important in this way, although it has been shown to evoke the expected cross-cultural differences and perception of depth on its own.

It is of course impossible to demonstrate that a psychological event, such as the perception of an illusion, *always* occurs, as demanded by **Wenderoth,** simply because we cannot investigate *all* possible variations. Gregory's (1968) data do show depth perception with a Müller–Lyer figure presented under "reduced conditions," that is, when it appears as an isolated luminous figure with no visible background. The implicit depth is simply there. It seems to be impossible to expurgate it without altering the figure; such an alteration would create an entirely

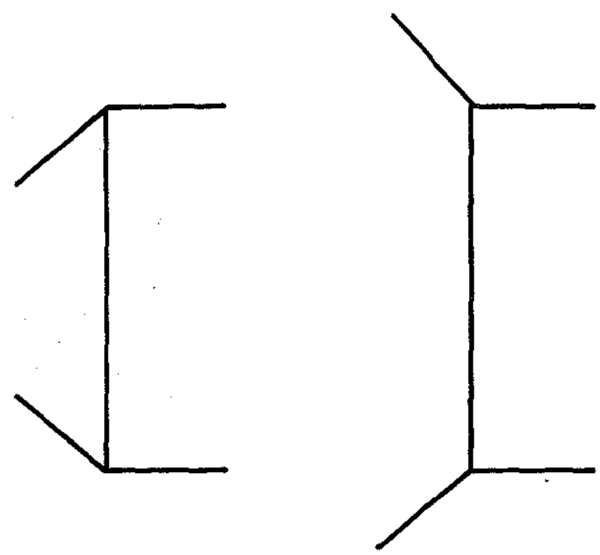


Figure 2 (Deregowski). The figure shows how the arrangement of lines used by Deregowski and Parker (1988) can be used to create stimuli similar to the Müller–Lyer illusion.

different stimulus, one that could no longer be called a Müller–Lyer illusion. One can postulate that presentation under less reduced conditions may cause the figure's implicit depth to disappear, but this seems unlikely, and without any supporting data it sounds like an unnecessary hypothetical complication. On the other hand, other data suggest that depth is clearly present in illusions under such conditions. The seemingly spatial transformations that affect plane figures, reported by Jerison (1967), Goldstein (1979), Deregowski and Parker (1988), and the target artaicle (sect. 2, para. 1 and 4), can be extended to the Müller–Lyer illusion. The linear arrangement used by Deregowski and Parker can be used to create stimuli that are half Müller –Lyer illusions (see Figure 2 of this Response). When viewed by a moving observer, these figures are subject to spatial transformations similar to those in the original figure. More important, this is also true of the Müller–Lyer figure, although in the latter case the effect is smaller, perhaps because of the symmetry of the stimulus (as Hochberg & Brooks's 1960 and Welford's 1970 observations would lead one to expect) or perhaps because of the absence of the clear baselines that horizontal elements provide in other figures. These observations seem to diminish the thrust of the comments on this issue.

The Ponzo illusion has also crawled into **Freeman's** commentary, disguised as a crocodile. The Ponzo-crocodile illusion does occur without elevation, but not, contrary to Freeman's suggestion, without implicit (Freeman uses the term "explicit," I take this to be a misprint) depth. Surely there is as much depth in this portrayal as there is in the converging lines formed by the rooftops and the railing tops on either the right or the left of the receding road in Freeman's figure. The suggestion that the tortoise might have been subject to perceptual intrusions is interesting and raises a problem about the extent to which a figure's cohesion invites intrusions and about the observer's tendency to make them. If the grapes/hair in Figure 15 were replaced by hair, and the subjects were then found to be more likely to see the figure as a face, and if this tendency were further increased by analogous changes of other figure elements, one could argue that it is not the elements' spatial separation but rather their nature that invites intrusive responses. I know of no relevant published data but would predict that the tendency to perceive "a face" increases with more truly facial features because each feature promotes the search for other cognate features. The facial arrangement of the features would accordingly become less important, but the face would most often be perceived with stimuli preserving a cohesive facial arrangement. In short, I accept that processing takes place in both directions, but it seems unlikely that all facial elements are equally important under these conditions. Coss's (1968) work, as well as animal studies by Hinton (1973), shows that given only a modicum of similarity both animals and men treat certain representations as if they were the represented objects. This is particularly so in the case of eyes. Changes to the "eyes" in Figure 15 would therefore have less effect than, say, changes to the hair. This is a result that **Hirtle** would presumably also anticipate on the basis of Maurer and Salapatek's (1976) data.

Halpern is right that the evidence shows that certain illusions are universally experienced. I agree with her and not with **Thro** who maintains that I hold (with Wittgenstein) that there are no figures that cause illusions universally. Halpern is also right in pointing out that the illusions experienced differ in magnitude from population to population. Segall et al.'s (1966) study, for example, shows a percentage discrepancy for the "inverted-t" form of the horizontal–vertical illusion ranging from 8 to 24 for adults in the 15 populations tested. This considerable discrepancy must have its origins somewhere; barring experimental errors, these origins must be either genetic or ecocultural or both. It is the difference in treatment of this discrepancy that forms the root of the disagreement between Halpern's view and the target article: To Halpern, these differences are of little consequence for she believes there is a core at which the experiences of all groups are essentially the same, and this core is what really matters. I do not share this view. There may well be a core. We can find whether it is there or not only by the removal and careful scrutiny of the "outer layers" of the phenomenon. This search for the core, assisted by cross-cultural studies, may turn out to be fruitless.

One must bear in mind how difficult it is to create a comprehensive taxonomy of illusions that, unlike colours, do not appear to have readily apprehensible "focal" versions and yet are subject to infinite variation in their effectiveness. Thus the modified version of the Müller–Lyer figure that **Weale** offers is very similar to the version used by Segall et al. (1966) in their classical study. In their stimuli not only were the figures "exploded" but the fins differed in colour from the shafts to make the task of comparing lengths more easily comprehensible. This diminishes the illusion somewhat but the effect is, as their data show, still there. This makes both the attribution of changes in illusion susceptibility and the establishment of a taxonomy of illusions difficult.

The classification of visual illusions that **Rose** puts forward seems to be suspect because the exemplars of the categories are neither mutually exclusive nor sufficiently differentiated. I do not see why the Necker cube cues are ambiguous whereas those of the two-pronged trident conflict when they are basically different combinations of the same units, as described by Biederman (1987); nor is it clear why Escher's drawing of a staircase is put in a separate category from the trident.

Perhaps the most startling illusions are those associated with the baroque church ceilings studied by Pirenne (1970). When Pirenne describes the experiences of a viewer looking at Pozzo's church he recognises, as the quotation cited by **Thro** shows, that the situation in which the viewer finds himself is optically unusual. Lacking awareness of the painting's surface (subsidiary awareness) the viewer does *not* see the picture "as a picture" but as a real object, and therefore the building appears to collapse above him as he moves from the predetermined stance. On the other hand, the extent to which a picture in a photograph, say, is seen not to change as it is viewed from various angles argues, according to Pirenne, for the presence of a compensatory effect of subsidiary awareness; here a "picture is seen as a picture." I see no disagreement between Pirenne's and my own interpretation of the latter case; nor do I think I have misrepresented him in either case.

It is not clear, however, that an awareness of the purely pictorial cues will necessarily eliminate transformations such as those observed by our viewer of Pozzo's ceiling. A viewer passing by Vermeer's *The Music Lesson* experiences similar, albeit less dramatic changes; he also does so when this picture is replaced by only three convergent lines representing the portrayed room's essential elements (Deregowski & Parker 1988). It appears, therefore, that not only do these three lines constitute elements similar to **Biederman**'s geons (identical, incidentally, with some of the trident's elements) but also that such elements are subject to apparent transformation with the observer's movement relative to the picture, as Jerison (1967) has noted (see Figure 1 of the target article). The question therefore arises: To what extent are such elements present in the famous ceiling? For if they are there in force then suppression of subsidiary awareness may not be an absolute prerequisite for the dramatic effect described by Pirenne.

These perceptual changes are much more noticeable in the case of the ceiling than in pictures such as those investigated by Goldstein (1979) and Deregowski and Parker (1988) because, in spite of the "deformations," these paintings convey likely views from a wide range of angles. It matters little to a viewer, for example, whether a road veers slightly to the left or to the right in the picture used by Goldstein; nor does it matter what configuration of lines is perceived in the basic geometric figure underlying the effect investigated by Deregowski and Parker. Because all *static* views are seen as equally legitimate and it is only a *change* that can be observed if the observer moves relative to the picture, it is this change that draws attention to the phenomenon. Not so in the case of paintings incorporating many architectural features. Changes with movement are observed in such paintings too, but the static views from various stances are not equally acceptable simply because sloping walls and columns and toppling cornices are not expected in a sound building. The extensions of the architectural structure (walls, columns, and so forth) are normally perceived as stable by the observer; this contrasts with the perceived deformation in the painted ceiling.

If the observed changes in the Pozzo ceiling are primarily due to the factor just described then there is clearly little advantage in testing subjects in Rome, Vienna, Lublin, and wherever else such ceilings can be found. If the effect is due to the observers' seeing the ceiling not as a picture but as an object then, clearly, the phenomenon has to do with the perception of real space rather than represented space and there is still no need to seek out Pozzo ceilings in particular.

The surprising perceptual effects of Pozzo ceilings might be said to result from unjustified conclusions the eye draws from the stimuli. A similar perceptual error occurs with such humble drawings as Figure 4 of the target article. The effect here is so strong that it baffles **Weale,** who fails to see that the figure is certainly impossible. The proof of the pudding is in the eating: If Weale constructs, using some pliable medium, as many pyramids as he wishes, each with four triangular faces, and decapitates them one by one, he will not be able to find a pyramid where three sloping and now cut edges are not concurrent when extended; and xecause in the commonly used systems of projection a point can only be projected as a point (not as two or three points) the extensions of these edge representations will likewise be concurrent in all drawings of the decapitated pyramids. They are not concurrent in Figure 4, however.

The impossible figures can be variously classified but all have 2/3d elements that make them especially interesting in the present context. One such figure is the two-pronged trident. **Thro** maintains that I use the trident to determine whether there are cross-cultural differences in depth perception; he advances the thesis that the trident has two components that independently render it "depth impossible," making it an "impossible solid" and hence entirely unusable for such a purpose. This distinction does not seem relevant, for if a representation is seen as a solid in the 2/3d sense the picture must convey depth, and the perceptual difficulties it presents may accordingly involve depth perception. This was indeed the view advanced by Deregowski (1969), but it was later challenged by the evidence of Young and Deregowski (1981) and is not put forward in the paper on which Thro comments (see sect. 8, para. 11, where I clearly state this). The argument of Young and Deregowski is that the younger (and less experienced) schoolchildren do perceive various elements of the figure as 3D but they fail to perceive that these elements are so combined as to create an impossible object.

How impossible is the fork? **Thro** states that it is impossible even as a flat object (a paper cutout). This is true, but it is *not* impossible as a flat object made of wire. Nor is it impossible, as Masterton and Kennedy (1975) show, as a cardboard structure. In discussing their attainment of the impossible they state: "because there is an object hypothesis (although highly unlikely) that resolves the incompatible depth cues that usually occur to a person 'perceiving' the trident it is an impossible figure which can be physically constructed using surfaces!" (p. 109). Hence, like the famous Reutersvard's triangle explored by Gregory (1968), the trident is not a truly impossible figure but rather a very unlikely one. It is nevertheless generally regarded as impossible because, as Kulpa (1987) rightly observes, "The property 'to be an impossible figure' is not the property of the drawing alone, but the property of the spatial interpretation chosen by a human observer" (p. 203).

A desirable study, not yet carried out as far as I know, would be to compare performance on the "two-pronged trident" task with performance on Street-type figures, which require the integration of pictorial elements but do not involve pictorial (2/3d) depth. Such a study could help determine the extent to which each of the two factors, that is, integration and perception of the trident's cues as 2/3d, is responsible for the difficulty of the trident figure. Notwithstanding this, it cannot be denied that the perceptual difficulties associated with this figure have to do with the perception of pictorial depth either directly through the failure to recognise the 3D "value" of the cues or, somewhat less directly, through the failure to see that they do not form an acceptable 2/3d arrangement.

The problem of picture metaphors mentioned above can be extended to the impossible figures. Just as **Kennedy** is concerned with visual and tactile parallels, Cresswell (1983), in discussing the structuring of meaning, considers the parallel between visual and semantic contradictions in response to an intellectual drive "to end up with" a set of possible worlds in which the sentence is true (p. 63). This suggests that the less sophisticated of Young and Deregowski's (1981) subjects might not have *failed* to notice the contradictions among various elements of the trident but noticed them and were unconcerned about them. This is an unlikely eventuality, because Deregowski and Bentley's (1987) study of Kxoe (Bushmen) children shows that those who find the "impossible" trident easy to copy tend to build distorted models of geometric figures. Thus, poor ability to integrate the stimuli appears to affect both tasks and, paradoxically, whilst helping the subjects in performing one of them, hinders them in the other.

In considering this interpretation of the Kxoe data one must nevertheless bear in mind the remote possibility that this group may be culturally so distinct as to cast doubt on extrapolations from the outcome. This caveat rests on the evidence presented by Bentley and Deregowski (1987) of three preschool groups: Kxoe, Zulu, and white English-speaking South Africans. The task was to identify representations of common objects drawn with segmented lines in a manner described by Murray and Szymczyk (1978). On this task the rural Kxoe were superior to both the Zulu and the white group even though these urban groups encounter pictures much more often. A tentative explanation (with some support, see Liddell 1986) is that the nonpictorial activities of the Kxoe foster skills relevant to picture perception (i.e., their skills are those represented by area B in Figure 25). Such an explanation accords well with Berry's (1971a; 1971b) suggestions about the effects of culture and environment on perception.

Perception of solid models. If the difficulties that the subjects experience with pictures were simply the result of the notion of representation alone, such difficulties would also be observable with three-dimensional models. **Hubbard, Baird & Ajmal,** as well as **Rose,** touch on this issue in their commentaries.

Several studies are relevant to the question of whether models of objects are treated differently in different cultures. Models (meaning figurines) are 3D stimuli that often differ in size and other attributes from the objects they represent although they remain spatially congruent (i.e., they are simply scaled-down objects).

With models, as with pictures, there are various levels of difficulty. The most fundamental of these is a failure to recognise that a model represents something; the less fundamental one is a failure to recognise a particular class of objects. There are no data showing the more basic of these difficulties; it seems unlikely that such data could be obtained from moderately remote populations, as the following studies show. Bisa schoolchildren and men from a remote village were required to name a model shown (i) in a photograph and (ii) in an array of models (Deregowski 1968a). The difference between the treatment of the models and the pictures by all subjects is shown by the frequencies with which an animal was given a name. The ratio of the instances in which the model was named and the photograph was not to the instances when the photograph was named but not the model was about 2:1, showing clearly the greater acceptability of the models. This is confirmed by the absence of a significant difference between Scottish and Zambian schoolchildren on a sorting task when models were used and the presence of such a difference when pictures were used (Deregowski & Serpell 1971).

A model is therefore "superior" to a picture; there seems to be no evidence (although the data are admittedly scanty) for cross-cultural differences in the perception of 3D models. The "superiority" of models is not surprising, because the superiority of objects over representations has been reported in a wide variety of tasks (Deregowski 1971a; Deregowski & Jahoda 1975; Klapper & Birch 1969; Sigel 1968). Because this evidence of superiority applies to smaller than lifesize models, the stress laid on the visual angle's importance by **Hubbard et al.** is not entirely justified. Furthermore, visual angle may be a more important variable in the case of drawings than in the case of solids (see **Weale**).

The extension of studies into nonpictorial (stereoscopic, kinetic) displays, as advocated by **Day**, seems likely to enrich the stimuli so greatly that one can no longer say that the stimuli are in the same class of representations. One would therefore be in some danger of falling into Mein Herr's predicament (Lewis Carroll 1893, p. 169):

> "That's another thing we've learned . . . map-making. But we've carried it much further than you. What do you consider the largest map that would be useful?" "About six inches to the mile." "Only six inches!" exclaimed Mein Herr. "We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to a mile!" "Have you used it much?" I enquired. "It has never been spread out, yet," said Mein Herr, "the farmers objected: they said it would cover the whole country, and shut out the sunlight." So we now use the country itself, as its own map, and I assure you it does nearly as well."

If this danger can be avoided or controlled, then such approaches may indeed prove helpful; some timid steps in this direction have already been taken (Deregowski 1974b; Dziurawiec & Deregowski 1987; Serpell & Deregowski 1972). Day's remarks may make it easier to overcome this timidity.

Three-dimensional models certainly provide an important baseline for the study of picture perception, as the Perkins and Deregowski (1982) experiment shows. Cross-cultural differences were observed when subjects were required to sort pictures of solids but not when they were asked to sort solids. The reasons for the difference are unclear; it hence seems imprudent to lay as great a stress on these observations as **Biederman** recommends. The results show that the Zimbabwean children regarded a greater range of pictures as representing a right angle than did their American counterparts. This range was broader than the range used by the Americans. However, the geometrically correct representations were wholly contained in the "American" range. There are two explanations of how these findings relate to the carpentered world hypothesis: (1) The experience of the carpentered world leads to the perception of a wide range of angles as right angles, so that this range includes angles that could not be geometrical projections of right angles. Or (2) such an experience makes the discrimination of right angles and nonright angles more precise. I would incline towards the second of these interpretations, thereby interpreting the results differently from Biederman.

Concluding comment. As the commentaries touch on far broader issues than those considered in the target article I have, in responding to them, tried to adduce further cross-cultural data and to tie together at least some loose ends brought to my attention. I have not been entirely successful; the persistent theme of the Author's Response is the lack of appropriate findings. This mirrors the state of cross-cultural studies of perception. In spite of their interest and scientific value, cross-cultural studies have progressed by fits and starts and have been propelled by the efforts of individual scholars rather than by those of schools. Some of the lacunae the present exchange revealed can still be filled, but some will gape forever because rapid social and demographic changes have completely eliminated certain populations; for example, it is very unlikely that a population could be found today that was entirely free of contact with pictorial materials. Such "lost" populations cannot find a substitute, as our discussion shows, in such populations as children, animals, or the brain-damaged.

Certain issues that can still be profitably investigated cross-culturally (sometimes, perhaps, only cross-culturally) nevertheless remain. The target article should therefore be seen not as an obituary for cross-cultural studies in perception but as an exhortation to further work. The commentaries show that such work could profitably be done on the problem of the perception of real space and represented space and they point the way ahead.

References

Letters a and r appearing before authors' initials refer to target article and response respectively.

Abbott, E. A. (1884/1950) *Flatland*. Seeley. Reprinted 6th edition. Blackwell. [DP]

Agbasiere, J. A. & Chukwujekwu, S. E. (1972) Teaching mechanical engineering design in Africa. *Chartered Mechanical Engineer* 19:62–64. [aJBD]

Ahluwalia, A. (1978) An intra-cultural investigation of susceptibility to "perspective" and "non-perspective" spatial illusions. *British Journal of Psychology* 69:237–41. [aJBD]

Anderson, H. H. & Anderson, G. L. (1964) *Projection techniques*. Prentice-Hall. [aJBD]

Anderson, R. (1979) *Art in primitive societies*. Prentice-Hall. [aJBD]

Annis, R. C. (1980) Bantu and Pygmy perceptual patterns: An eco-cultural study. Ph.D. thesis, University of Strathclyde. [aJBD]

Annis, R. C. & Frost, B. (1973) Human visual ecology and orientation anisotropies in acuity. *Science* 182:729–31. [rJBD, DP]

Armstrong, C. (1893) *Cusack's model drawing*. City of London School of Art. [NHF]

Arnhoff, F. N. & Damianopoulos, E. N. (1964) Self-body recognition and schizophrenia. *Journal of Genetic Psychology* 70:353–61. [aJBD]

Ausburn, F. B. & Ausburn, L. J. (1983) Visual analysis skills among two populations in Papua New Guinea. *Educational Communication and Technology Journal* 31:112–22. [aJBD]

Barley, N. (1986) *The innocent anthropologist*. Penguin Books. [aJBD]

Bartel, K. (1958) *Perspektywa malarska*. Panstwowe Wydawnictwo Naukowe. [rJBD]

Bauer, R. M. (1986) The cognitive psychophysiology of prosopagnosia. In: *Aspects of face processing*, ed. H. D. Ellis, M. A. Jeeves, F. Newcombe & A. Young. Martinus Nijhoff. [aJBD]

Beveridge, W. M. (1935) Racial difference in phenomenal regression. *British Journal of Psychology* 26:59–62. [aJBD]

Beach, H. P. (1901) *Geography and atlas of Protestant missions*. Student Volunteer Movement for Foreign Missions. [arJBD]

Bentley, A. M. & Deregowski, J. B. (1987) Pictorial experience as a factor in the recognition of incomplete pictures. *Applied Cognitive Psychology* 1:209–16. [rJBD]

Berkeley, G. (1709) *A new theory of vision*, ed. A. A. Luce & T. E. Jessop. London. [JE]

Berlin, B. & Kay, P. (1969) *Basic color terms*. University of California Press. [TI]

Bermingham, P. J. (1976) Racial variation in aptitudes. *The Times Higher Education Supplement*: Nov. 19, p. 10, col. D. [aJBD]

Berry, J. W. (1966) Temne and Eskimo perceptual skills. *International Journal of Psychology* 1:207–29. [aJBD]

(1968) Ecology, percepteual development and the Müller-Lyer illusion. *British Journal of Psychology* 59:205–10. [arJBD]

(1971a) Müller-Lyer susceptibility: Culture, ecology, and race. *International Journal of Psychology* 6:193–97. [arJBD, SC, RHP]

(1971b) Ecological and cultural factors in spatial perceptual development. *Canadian Journal of Behavioural Science* 3:324–36. [arJBD]

Biederman, I. (1987) Recognition-by-components: A theory of human image understanding. *Psychological Review* 94:115–47. [rJBD, IB]

(1988) Aspects and extensions of a theory of human image understanding. In: *Computational processes in human and machine vision: An interdisciplinary perspective*, ed. Z. Pylyshyn. Ablex. [IB]

Biederman, I., Mezzanotte, R. J. & Rabinowitz, J. C. (1982) Scene perception: Detection and judging objects undergoing relational violations. *Cognitive Psychology* 14:143–77. [SCH]

Biesheuvel, S. (1952a) The study of African ability, Part 1. The intellectual potentialities of Africans. *African Studies* 11:45–48. [aJBD]

(1952b) The study of African ability, Part 2. A survey of some research problems. *African Studies* 11:105–17. [aJBD]

Binet, A. (1980) Perception d'enfant. *Revue Philosophique* 30:512–14. [aJBD]

Binnie-Dawson, J. L. M. & Choi, P. P.-C. (1982) A study of perceptual and cultural cues in Chinese and Western paintings. *Psychologia* 25:18–31. [aJBD]

Blakemore, C. (1973) The baffled brain. In: *Illusion in nature and art*, ed. R. L. Gregory & E. H. Gombrich. Duckworth. [aJBD]

Boniuk, V. (1973) Refractive problems in native people. *Canadian Journal of Ophthalmology* 8:229–33. [SC]

Bornstein, M. (1973) Color vision and color naming: A psychophysical hypothesis of cultural difference. *Psychological Bulletin* 80:257–85. [SC]

Boselie, F. & Leeuwenberg, E. (1986) A test of the minimum principle requires a perceptual coding system. *Perception* 15:331–54. [DR]

Braunstein, M. L. (1976) *Depth perception through motion*. Academic Press. [RHD]

Braunstein, M. L. & Anderson, G. J. (1984) Shape and depth perception from parallel projections of three dimensional motion. *Journal of Experimental Psychology: Human Perception and Performance* 10:749–60. [RHD]

Brigham, J. C. (1986) Influence of race on face recognition. In: *Aspects of face processing*, ed. H. D. Ellis, M. A. Jeeves, F. Newcombe & A. Young. Martinus Nijhoff. [aJBD]

Brislin, R. (1974) The Ponzo illusion: Additional cues, age, orientation and culture. *Journal of Cross-cultural Psychology* 5:139–61. [aJBD]

Brislin, R. W. & Keating, C. F. (1976) Cultural differences in perception of the three-dimensional Ponzon illusion. *Journal of Cross-cultural Psychology* 7:397–411. [aJBD, TLH]

Brown, L. B. (1969) The 3D reconstruction of a 2D visual display. *Journal of Genetic Psychology* 115:257–62. [aJBD]

Bruce, V. & Young, A. W. (1986) Understanding face recognition. *British Journal of Psychology* 77:305–27. [HDE]

Bryant, P. E. (1985) The distinction between knowing when to do a sum and knowing how to do it. *Educational Psychology* 5:207–16. [NHF]

Bryson, N. (1983) *Vision and painting: The logic of the gaze*. Macmillan. [rJBD, NHF]

Cabe, P. A. (1980) Picture perception in non-human subjects. In: *The perception of pictures*, vol. 2, ed. M. A. Hagen. Academic Press. [aJBD]

Caldwell, E. C. & Hall, V. C. (1970) Concept learning in discrimination tasks. *Developmental Psychology* 2:41–48. [DWS]

Caron-Pargue, J. (1985) *Le dessin du cube chez l'enfant: Organisations et réorganisations de codes graphiques*. Bern: P. Lang. [JC-P]

(1987a) Une approche de la genèse de la production graphique. Le dessin du parallélépipède. In: *Le dessin technique*, ed. P. Rabardel & A. Weill-Fassina. Hermes. [rJBD, JC-P]

(1987b) Analyse d-instructions graphiques pour faire un noeud: La filiation des significations dans des dessins d'enfants. *Archives de Psychologie* 55:153–73. [JC-P]

Carr, H. A. (1935) *An introduction to space perception*. Hafner. [JE]

Carraher, T. N., Carraher, D. W. & Schliemann, A. D. (1985) Mathematics in the streets and in schools. *British Journal of Developmental Psychology* 3:21–30. [NHF]

Carroll, Lewis (1893) *Sylvie and Bruno concluded*. Macmillan. [rJBD]

Cheng, K. (1986) A purely geometric model in the rat's spatial representation. *Cognition* 23:149–78. [DMW]

Cheng, K. & Gallistel, C. R. (1984) Testing the geometric power of an animal's spatial representation. In: *Animal cognition*, ed. H. L. Roitblat, T. G. Bever & H. S. Terrace. Erlbaum. [DMW]

Chesterton, G. K. (1929) *The scandal of Father Brown. The point of a pin*. Cassell. [DP]

Chwistek, L. (1924/1960) *Wielosc rzeczywistosci w sztuce*. Czytelnik. [rJBD]

(1961) *Pisma filozoficzne i logiczne*. Panstwowe Wydawnictwo Naukowe. [rJBD]

Clemmesen, V. & Luntz, M. H. (1976) Lens thickness and angle-closure glaucoma. *Acta Ophtamologica* 54:193–97. [rJBD]

Cole, M., Gay, J., Glick, J. & Sharp, D. W. (1971) *The cultural context of learning and thinking*. Basic Books. [aJBD]

Cole, M. & Scribner, S. (1974) *Culture and thought: A psychological introduction*. John Wiley. [arJBD]

Colomb, E. H. A. & Dasen, P. R. (1986) La percepteion des relations spatiales de dessin et le development des operations concretes. *International Journal of Psychology* 21:71–90. [aJBD]

Conan Doyle, A. C. (1890) *The sign of four*. Spencer Blackett. [DP]

Conkey, M. (1987) New approaches in the search for meaning? A review of research in "Paleolithic art." *Journal of Field Archaeology* 14:413–30. [CSP]

Conley, B. (1985) Theories of pictorial representation: Goodman's relativism and the similarity theory. Ph.D. thesis, University of Minnesota. [aJBD]

Cook, B. L. (1980) Picture communication in Papua New Guinea. *Educational Broadcasting International* 13:78–83. [rJBD]

Coombs, C. H. (1983) *Psychology and mathematics*. University of Michigan Press. [SCH]

Coren, S. (1969) The influence of optical aberrations on the magnitude of the Poggendorff illusion. *Perception and Psychophysics* 6:185–86. [SC]

(1986) An efferent component in the visual perception of direction and extent. *Psychological Review* 93:391–410. [SC]

Coren, S. & Girgus, J. S. (1978a) *Seeing is deceiving: The psychology of visual illusions*. Erlbaum. [rJBD, SC, DFH]

(1978b) Visual illusions. In: *Handbook of sensory physiology*, vol. 8, *Perception*, ed. H. Leibowitz & H.-L. Teuber. Springer-Verlag. [SC]

Coren, S. & Miller, J. (1974) Size contrasts as a function of figural similarity. *Perception and Psychophysics* 16:355–57. [aJBD]

Coren, S. & Porac, C. (1978) Iris pigmentation and visual-geometric illusions. *Perception* 7:473–78. [rJBD, SC]

(1979) Heritability in visual-geometric illusions: A family study. *Perception* 8:303–9. [SC]

(1983) The creation and reversal of the Mueller-Lyer illusion through attentional manipulation. *Perception* 12:49–54. [SC]

(1984) Structural and cognitive components in the Mueller-Lyer illusion assessed via Cyclopean presentation. *Percepteion and Psychophysics* 35:313–18. [SC]

Coren, S., Ward, L. M., Porac, C. & Fraser, R. (1978) The effect of optical blur on visual-geometric illusions. *Bulletin of the Psychonomic Society* 11:390–92. [SC]

Coss, R. G. (1968) The ethological command in art. *Leonardo* 1:273–87. [rJBD]

Costall, A. (1985) How meaning covers the traces. In: *Visual order: The nature and development of pictorial representation*, ed. N. H. Freeman & M. V. Cox. Cambridge University Press. [NHF]

Cox, M. V. (1985) One object behind another: Young children's use of array-specific or view-specific representations. In: *Visual order: The nature and development of pictorial representation*, ed. N. H. Freeman & M. V. Cox. Cambridge University Press. [NHF]

Creswell, M. J. (1983) Highly impossible scene. In: *Meaning, use and interpretation of language*, ed. R. Bauerle, C. Schwarze & A. von Stechow. Walter de Gruyter. [rJBD]

Cronbach, L. J (1957) The two disciplines of scientific psychology. *American Psychologist* 12:671–84. [FJRV]

Dana, R. H. & Voight, W. H. (1962) The Seven-Squares Test. *Perceptual and Motor Skills* 15:751–53. [aJBD]

Dasen, P. R. (1974) The influence of ecology, culture and European contact on cognitive development of Austrailian Aborigines. In: *Culture and cognition: Readings in cross-cultural psychology*, ed. J. W. Berry & P. R. Dasen. Methuen. [rJBD]

Davenport, R. K. & Rogers, C. M. (1971) Perception of photographs by apes. *Behaviour* 39:318–20. [aJBD]

Davies, T. N. (1973) Visual perception of engineering drawings. *Engineering Designer* 4:22–31. [aJBD]

Davis, A. M. (1985) The canonical bias: Young children's drawings of familiar objects. In: *Visual order: The nature and development of pictorial representation*, ed. N. H. Freeman & M. V. Cox. Cambridge University Press. [rJBD, NHF]

Davis, C. M. (1970) Education and susceptibility to the Müller–Lyer illusion among the Banyakole. *Journal of Social Psychology* 82:25–34. [aJBD]

Davis, C. M. & Carlson, J. A. (1970) A cross-cultural study of the strength of Müller–Lyer illusion as a function of attentional factors. *Journal of Personality and Social Psychology* 16:403–10. [aJBD]

Davis, W. (1986) The origins of image making. *Current Anthropology* 27:193–215. [CSP]

(1987) Replication and depiction in Paleolithic art. *Representations* 19:111–47. [CSP]

Dawson, J. L. M. (1967a) Cultural and physiological influences upon spatial-perceptual processes in West Africa, Part 1. *International Journal of Psychology* 2:115–28. [aJBD]

(1967b) Cultural and physiological influences upon spatial perceptual processes in West Africa, Part 2. *International Journal of Psychology* 2:171–85. [aJBD]

DeLoache, J. S. (1987) Rapid change in the symbolic functioning of very young children. *Science* 238:1556–57. [RMD]

DeLoache, J. S., Strauss, M. S. & Maynard, J. (1979) Picture perception in infancy. *Infant Behavior and Development* 2:79–89. [aJBD]

Deregowski, J. B. (1968a) Pictorial recognition in subjects from a relatively pictureless environment. *African Social Research* 5:356–64. [rJBD]

(1968b) Difficulties in pictorial depth perception in Africa. *British Journal of Psychology* 59:195–204. [arJBD]

(1969) Perception of the two-pronged trident by two- and three-dimensional perceivers. *Journal of Experimental Psychology* 82:9–13. [aJBD, EBT]

(1971a) Responses mediating pictorial recognition. *Journal of Social Psychology* 84:27–33. [arJBD, FJRV]

(1971b) Orientation and perception of pictorial depth. *International Journal of Psychology* 6:111–14. [rJBD]

(1971c) Illusion and culture. In: *Illusion in nature and art*, ed. R. L. Gregory & E. H. Gombrich. Duckworth. [EBT]

(1974a) Effect of symmetry upon reproduction of Kohs type figures: An African Study. *British Journal of Psychology* 65:93–102. [aJBD]

(1974b) Teaching African children pictorial depth perception: In search of a method. *Perception* 3:309–12. [rJBD]

(1976a) Implicit shape constancy as a factor in pictorial perception. *British Journal of Psychology* 67:23–29. [aJBD]

(1976b) Coding and drawing of simple geometric stimuli by Bukusu school children in Kenya. *Journal of Cross-cultural Psychology* 7:195–208. [arJBD]

(1976c) "Principle of Economy" and perception of pictorial depth: A cross-cultural comparison. *International Journal of Psychology* 11:15–22. [rJBD]

(1977) A study of orientation errors in response to Kohs' type figures. *International Journal of Psychology* 12:183–91. [aJBD]

(1980a) *Illusions, patterns and pictures*. Academic Press. [arJBD]

(1980b) Some aspects of perceptual organisation in the light of cross-cultural evidence. In: *Studies in cross-cultural psychology*, ed. N. Warren. Academic Press.

(1983) A nineteenth-century Scottish missionary in Africa, and some psychological speculations. In: *An African miscellany for John Hargreaves*, ed. R. C. Bridges. Aberdeen University Press. [aJBD]

(1984) *Distortion in art: The eye and the mind*. Routledge and Kegan Paul. [arJBD]

(1986) Kazimierz Bartel's observations on drawings of children and illiterate adults. *British Journal of Developmental Psychology* 4:331–33. [rJBD]

(1988) *Oko i obraz – studium psychologiczne*. Państwowe Wydawnictwo Naukowe. [arJBD]

Deregowski, J. B. & Bentley, A. M. (1986) Perception of pictorial space by Bushmen. *International Journal of Psychology* 21:743–52. [aJBD, DP]

(1987) Seeing the impossible and building the likely. *British Journal of Psychology* 78:91–97. [rJBD]

Deregowski, J. B. & Byth, W. (1970) Hudson's pictures in Pandora's box. *Journal of Cross-cultural Psychology* 1:315–23. [arJBD]

Deregowski, J. B. & Dziurawiec, S. (1986) Some aspects of comprehension of technical diagrams: An intercultural study. *Le Travail Humain* 49:43–60. [aJBD]

(1987) The effect of subject's sophistication on responses to spatial tasks. In: *Le dessin technique*, ed. P. Rabardel & A. Weill-Fassina. Hermes. [rJBD]

Deregowski, J. B. & Jahoda, G. (1975) Efficacy of objects, pictures and words in a simple learning task. *International Journal of Psychology* 12:19–25. [arJBD, FJRV]

Deregowski, J. B., Muldrow, E. S. & Muldrow, W. F. (1972) Pictorial recognition in a remote Ethiopian population. *Perception* 1:417–25. [aJBD, IB, HDE, TLH, HM]

Deregowski, J. & Parker, D. (1988) On a changing perspective illusion within Vermeer's "The Music Lesson." *Perception* 17:13–21. [arJBD]

Deregowski, J. B. & Serpell, R. (1971) Performance on a sorting task: A cross-cultural experiment. *International Journal of Psychology* 6:273–81. [arJBD]

Deregowski, J. B. & Strang, P. (1986) On the drawing of a cube an its derivatives. *British Journal of Developmental Psychology* 4:323–30. [NHF]

De Renzi, E. (1986) Current issues on prosopagnosia. In: *Aspects of face processing*, ed. H. D. Ellis, M. A. Jeeves, F. Newcombe & A. Young. Martinus Nijhoff. [aJBD]

Derrington, A. M. (1978) Development of selectivity in kitten striate cortex. *Journal of Physiology (London)* 276:46–47 (Proceedings). [RAW]

Donaldson, M. (1978) *Children's minds*. Fontana. [NHF]

Doob, L. W. (1961) *Communication in Africa: A search for boundaries*. Yale University Press. [arJBD]

Downs, R. M. & Liben, L. S. (1988) Through a map darkly: Understanding maps as representations. *Genetic Epistemologist* 16:11–18. [RMD]

Duncan, H. F., Gourlay, N. & Hudson, W. (1973) A study of pictorial perception among Bantu and white primary school children in South Africa. *Witwatersrand University Press*. [arJBD]

Duthie, R. K. (1985) The adolescent's point of view. Studies of forms in conflict. In: *Visual order: The nature and development of pictorial representation*, ed. N. H. Freeman & M. V. Cox. Cambridge University Press. [NHF]

Dziurawiec, S. & Deregowski, J. B. (1986a) Construction errors as a key to perceptual difficulties encountered in reading technical drawings. *Ergonomics* 29:1203–12. [arJBD]

(1986b) Time as a factor in a spatial task. *International Journal of Psychology* 21:177–87. [rJBD]

(1987) Investigation of perception of stationary and moving geometrical figures. In: *Le dessin technique*, ed. P. Rabardel & A. Weill-Fassina. Hermes. [rJBD]

Ebert, P. (1976) Effects of lightness contrast and fundus pigmentation on age-related decrement in magnitude of the Mueller–Lyer illusion. *Perceptual and Motor Skills*, 42:1276–78. [RHP]

Ebert, P. C. & Pollack, R. H. (1972) Magnitude of the Mueller–Lyer illusion as a function of hue, saturation, and fundus pigmentation. *Psychonomic Science* 26:225–26. [RHP]

(1973a) The effect of lightness contrast, tachistoscopic duration and fundus pigmentation on the magnitude of the Mueller–Lyer illusion. *American*

Journal of Optometry and Archives of American Academy of Optometry 50:872–79. [RHP]

(1973b) Some factors affecting magnitude of the Mueller–Lyer illusion. *Perceptual and Motor Skills* 37:433–340. [RHP]

Eckhardt, R. A. (1966) Foveal luminosity functions of five Negroes in relation to macular and skin pigmentation. Unpublished doctoral dissertation, Fordham University. [RHP]

Eco, U. (1976) *A theory of semiotics*. Indiana University Press. [CSP]

Eliot, J. (1987) *Models of psychological space*. Springer-Verlag. [JE]

Eliot, J. & Smith, I. M. (1983) *Spatial tests*. National Foundation for Educational Research (NFER)-Nelson. [aJBD]

Elkind, D. (1969) Development studies in figurative perception. In: *Advances in child development and behavior*, ed. E. L. Lipsitt & H. W. Reese. Academic Press. [arJBD, DWS]

Elkind, D., Koegler, R. & Go, E. (1964) Studies in perceptual development II: Part-whole perception. *Child Development* 35:81–90. [rJBD]

Ellis, H. D. (1981) Theoretical aspects of face recognition. In: *Perceiving and remembering faces*, ed. G. Davies, H. D. Ellis & J. Shepherd. Academic Press. [arJBD, PW]

Ellis, H. D., Jeeves, M., Newcombe, F. L. & Young, A. W. (1986) *Aspects of face processing*. Martinus Nijhoff. [aJBD]

Ellis, H. D. & Young, A. W. (1988) *Human cognitive neuropsychology*. Erlbaum. [HDE]

Ernst, B. (1986) *Het begoochlede oog: Onmogelijke en meersinninge figuren*. Meulenhoff. [aJBD]

Feldman, J. A. (1985) Four frames suffice: A provisional model of vision and space. *Behavioral and Brain Sciences* 8:265–89. [SCH]

Ferenczi, V. (1966) *La perception de l'espace projectif*. Didier. [rJBD]

Fernau, J. (1958) *Encyclopaedia of old masters*. Thames & Hudson. [RAW]

Finke, R. A. (1980) Levels of equivalence in imagery and perception. *Psychological Review* 87:113–32. [TLH]

Finke, R. A. & Shepard, R. N. (1986) Visual functions of mental imagery. In: *Handbook of perception and human performance*. Vol. 2: *Cognitive processes and performance*, ed. K. R. Boff, L. Kaufman & J. P. Thomas. John Wiley. [TLH]

Fisher, G. H. (1968) *The frameworks for perceptual localization*. University of Newcastle UponTyne. [RHP]

Fitzpatrick, G. E. (1964) An investigation of the rule of macular pigmentation in spectral sensitivity to the short wavelengths. Unpublished doctoral dissertation, Fordham University. [RHP]

Fodor, J. A. (1975) *The language of thought*. Harvester. [DR]

(1983) *Modularity of mind*. MIT Press. [JC-P]

Fodor, J. A. & Pylyshyn, Z. W. (1988) Connectionism and cognitive architecture: A critical synthesis. *Cognition* 28:3–71. [DR]

Forge, A. (1970) Learning to see in New Guinea. In: *Socialization*, ed. P. Mayer. Tavistock. [arJBD, IB, HM]

Fortes, M. (1940) Children's drawings among the Tallensi. *Africa* 13:293–95. [aJBD]

(1981) Tallensi children's drawings. In: *Universals of human thought*, ed. B. Lloyd & J. Gay. Cambridge University Press. [aJBD]

Freedman, S. J. (1968) *Neurophysiology of spatially-oriented behavior*. Dorsey Press. [JE]

Freeman, N. H. (1980) *Strategies of representation in young children: Analysis of spatial skills and drawing processes*. Academic Press. [rJBD, DR]

(1986) How should a cube be drawn? *British Journal of Developmental Psychology* 4:317–22. [NHF]

(1987) Current problems in the development of representational picture-production. *Archives de Psychologie* 55:127–52. [NHF]

Freeman, N. H. & Cox, M. V. (1985) *Visual order: The nature and development of pictorial perception*. Academic Press. [JE]

Freeman, N. H., Evans, D. & Willats, J. (1988) Symposium overview: The computational approach to projective drawing-systems. Paper given at the Third European Conference on Developmental Psychology, Budapest, June 15–19. [NHF]

Furth, H. G. (1968) Piaget's theory of knowledge: The nature of representation and interiorization. *Psychological Review* 75(2):143–54. [JE]

Fussell, D. & Haaland, A. (1978) Communicating with pictures in Nepal: Results of practical study in visual education. *Educational Broadcasting International* 11:25–31. [rJBD]

Ghent, L. (1956) Perception of overlapping embedded figures by children of different ages. *American Journal of Psychology* 69:575–87. [aJBD]

Gibson, E. J. (1988) Levels of description and constraints on perceptual development. In: *Perceptual development in infancy*, ed. A. Yonas. Erlbaum. [DWS]

Gibson, E. J., Gibson, J. J., Pick, A. D. & Osser, H. (1962) A developmental study of the discrimination of letter-like forms. *Journal of Comparative and Physiological Psychology* 55:897–906. [DWS]

Gibson, J. J. (1950) *The perception of the visual world*. George Allen & Unwin. [RHD]

(1971) The information available in pictures. *Leonardo* 4:27–35. [aJBD]

(1978) The ecological approach to the visual perception of pictures. *Leonardo* 11:227–35. [aJBD, GJ]

(1979) *The ecological approach to visual perception*. Houghton Mifflin. [aJBD, GJ]

Gilhooly, K. J., Wood, M., Kinnear, P. R. & Green, C. (1988) Skill in map reading and memory for maps. *Quarterly Journal of Experimental Psychology* 40A:87–107. [rJBD]

Gladwin, T. (1970) *East is a big bird*. Harvard University Press. [rJBD]

Goldsmith, E. (1984) *Research into illustration*. Cambridge University Press. [arJBD]

Goldstein, E. B. (1979) Rotation of objects in pictures viewed at an angle: Evidence for different properties of two types of pictorial space. *Journal of Experimental Psychology – Human Perception* 5:78–87. [arJBD]

Gombrich, E. H. (1962) *Art and illusion*. Phaidon Press. [aJBD, RAW]

(1979) On J. J. Gibson's approach to the visual perception of pictures: Letters. *Leonardo* 12:174–75. [aJBD]

(1982) *The image and the eye*. Cornell University Press. [JMK]

Goodman, N. (1969) *Languages of art*. Oxford University Press. [aJBD]

(1968) *Languages of art*. Bobbs-Merrill. [EBT]

Goodnow, J. J., Wilkins, P. & Dawes, L. (1986) Acquiring cultural forms: Cognitive aspects of socialisation illustrated by children's drawings and judgements of drawings. *International Journal of Behavioral Development* 9:1–21. [NHF]

Granrud, C. E., Yonas, A. & Opland, E. A. (1985) Infants' sensitivity to depth cue of shading. *Perception of Psychophysics* 37:415–19. [rJBD]

Gregor, A. J. & McPherson, D. A. (1965) A study of susceptibility to geometric illusion among cultural sub-groups of Australian Aborigines. *Psychologia Africana* 11:1–13. [arJBD]

Gregory, R. L. (1965) Seeing in depth. *Proceedings of the Royal Institution* 40:311. [aJBD]

(1968) *Eye and brain*. World University Library. [arJBD]

(1970) *The intelligent eye*. Weidenfeld and Nicolson. [aJBD, DP, DR, EBT, RAW]

(1973) The confounded eye. In: *Illusion in nature and art*, ed. R. L. Gregory & E. H. Gombrich. Duckworth. [arJBD]

(1981) *Mind in Science*. Weidenfeld and Nicolson. [DR]

Grigg, R. (1984) Relativism and pictorial realism. *Journal of Aesthetics and Art Criticism* 24:398–407. [rJBD]

Guthrie, G. M., Sinaiko, H. W. & Brislin, R. (1971) Non-verbal abilities of Americans & Vietnamese. *Journal of Social Psychology* 84:183–90. [aJBD]

Hagen, M. A. (1974) Picture perception: Toward a theoretical model. *Psychological Bulletin* 81:471–97. [aJBD]

(1976) Influence of picture surface and station point on the ability to compensate for oblique view in pictorial perception. *Developmental Psychology* 12:57–63. [aJBD]

(1980) Generative theory: A perceptual theory of pictorial representation. In: *The perception of pictures*, vol. 2, ed. M. A. Hagen. Academic Press. [aJBD]

Hagen, M. A. & Johnson, M. M. (1977) Hudson pictorial depth perception test: Cultural content and question with a Western sample. *Journal of Social Psychology* 101:3–11. [aJBD]

Hagino, G. (1976) The effect of slant on perceived distance. *Hiroshima Forum for Psychology* 3:3–22. [NHF]

Halpern, D. F. (1986) *Sex differences in cognitive abilities*. Erlbaum. [DFH]

Harnad, S. (1987) *Categorical perception: The groundwork of cognition*. Cambridge University Press. [rJBD]

Harris, D. H. & Chaney, F. B. (1969) *Human factors in quality assurances*. John Wiley. [rJBD]

Harrison, A. (1987) Dimensions of meaning. In: *Philosophy and the visual arts*, ed. A. Harrison. Reidel. [NHF]

Hecaen, H. (1981) The neuropsychology of face recognition. In: *Perceiving and remembering faces*, ed. G. Davies, H. D. Ellis & J. Shepherd. Academic Press. [aJBD]

Herskovits, M. J. (1948) *Man and his works*. Knopf. [aJBD]

Herskovits, M. J., Campbell, D. T. & Segall, M. H. (1956) *Materials for a cross-cultural study of perception*. Bobbs-Merill. [aJBD]

Heusser, H. (1968) Ein frei galhaltener Krallenaffe (Callithrix jacchus) erkent Bilder. *Zeitshrift für Tierpsychologie* 25:710–18. [aJBD]

Hinton, H. E. (1973) Natural deception. In: *Illusion in nature and art*, ed. R. L. Gregory & E. H. Gombrich. Duckworth. [arJBD]

Hochberg, J. (1972) The representation of things and people. In: *Art,*

perception and reality, ed. E. H. Gombrich, J. Hochberg & M. Black. The Johns Hopkins University Press. [rJBD]
(1978) *Perception*. Prentice-Hall. [aJBD]
Hochberg, J. & Brooks, V. (1960) The psychophysics of form reversible perspective drawings of spatial objects. *American Journal of Psychology* 73:337–54. [rJBD]
(1962) Pictorial recognition as an unlearned ability: A study of one child's performance. *American Journal of Psychology* 75:624–28. [aJBD, IB, HDE]
Howard, I. P. & Templeton, W. R. (1966) *Human spatial orientation*. Wiley. [JE]
Hubbard, T. L. (1988) Temporal aspects of mental representation: A psychological approach. Doctoral dissertation, Dartmouth College. [TLH]
Hubbard, T. L. & Baird, J. C. (1988) Overflow, first-sight, and vanishing point distances in visual imagery. *Journal of Experimental Psychology: Learning, Memory & Cognition* 14:641–49. [TLH]
Hubbard, T. L., Kall, D. & Baird, J. C. (in press) Memory, imagery, and size-distance invariance. *Memory & Cognition*. [TLH]
Hudson, W. (1960) Pictorial depth perception in sub-cultural groups in Africa. *Journal of Social Psychology* 52:183–208. [arJBD, JE, DFH, GJ, DWS]
(1962) Pictorial perception and educational adaptation in Africa. *Psychologia Africana* 9:226–39. [aJBD, DFH]
(1967) The study of the problem of pictorial perception among unacculturated groups. *International Journal of Psychology* 2:89–107. [arJBD, JE, DFH, DWS]
Humphrey, N. K. & Keeble, G. R. (1974) The reaction of monkeys to "fearsome" pictures. *Nature* 251:500–502. [aJBD]
Humphreys, G. W. & Riddoch, M. J. (1984) Routes to object constancy: Implications from neurological impairments of object constancy. *Quarterly Journal of Experimental Psychology* 36A:385–415. [NHF]
(1987) *To see but not to see: A case study of visual agnosia*. Erlbaum. [HDE]
Hutchins, E. (1983) Understanding Micronesian navigation. In: *Mental models*, ed. D. Gentner & A. L. Stevens. Erlbaum. [SCH]
Indow, T. (1979) Alleys in visual space. *Journal of Mathematical Psychology* 19:221–58. [TI]
(1982) An approach to geometry of visual space with no a priori mapping functions: Multidimensional mapping according to Riemannian metrics. *Journal of Mathematical Psychology* 26:204–36. [TI]
Indow, T. & Watanabe, T. (1984) Parallel- and distant-alleys on horopter plane in the dark. *Perception* 13:144–54. [TI]
Ireson, J. & McGurk, H. (1985) Utilization of static and kinetic information for depth by young Malawians. *Journal of Experimental Child Psychology* 40:233–43. [HM]
Ishak, I. G. H. (1952a) The spectral chromaticity coordinates for one British observer and eight Egyptian trichromats. *Journal of the Optometric Society of America* 42:529–54. [RHP]
(1952b) The photopic luminosity curve for a group of fifteen Egyptian trichromats. *Journal of the Optometric Society of America* 42:534–39. [RHP]
Ittelson, W. H. (1973) *Environment and cognition*. Seminar. [JE]
Jahoda, G. (1956) Assessment of abstract behaviour in a non-Western culture. *Journal of Abnormal and Social Psychology* 53:237–43. [aJBD]
(1966) Geometric illusions and environment: A study in Ghana. *British Journal of Psychology* 57:193–99. [aJBD, RHP]
(1971) Retinal pigmentation, illusion susceptibility, and space perception. *International Journal of Psychology* 6:199–208. [rJBD, RHP]
(1975) Retinal pigmentation and space perception: A failure to replicate. *Journal of Social Psychology* 97:133–34. [rJBD]
(1976) Reproduction of Kohs-type drawings by Ghanaian children: Orientation error revisited. *British Journal of Psychology* 67:203–11. [aJBD]
(1978) Cross-cultural study of factors influencing orientation errors in reproduction of Kohs-type figures. *British Journal of Psychology* 69:45–57. [aJBD]
(1982) *Psychology and anthropology: A psychological perspective*. Academic Press. [rJBD]
(1983) The cross-cultural emperor's conceptual clothes: The emic-etic issue revisited. In: *Expiscations in cross-cultural psychology*, ed. J. B. Deregowski, S. Dziurawiec & R. C. Annis. Swets & Zeitlinger. [rJBD]
Jahoda, G., Deregowski, J. B., Ampene, E. & Williams N. (1977) Pictorial recognition as an unlearned ability: A replication with children from pictorially deprived environments. In: *The child's representation of the world*, ed. G. Butterworth. Plenum Press. [rJBD]
Jahoda, G. & McGurk, H. (1974a) Pictorial depth perception in Scottish and Ghanaian children: A critique of some findings with Hudson's test. *International Journal of Psychology* 9:255–67. [aJBD, HM]
(1974b) Development of pictorial depth perception in cross-cultural replications. *Child Development* 45:1042–47. [arJBD, HM]
(1974c) Pictorial depth perception: A developmental study. *British Journal of Psychology* 65:141–49. [arJBD]
(1982) The development of picture perception in children from different cultures. In: *Cultural Perspectives on Child Development*, ed. D. A. Wagner & H. W. Stevenson. Freeman. [HM]
Jahoda, G. & Stacey, B. (1970) Susceptibility to geometrical illusions according to culture and professional training. *Perception and Psychophysics* 7:179–84. [arJBD]
Jenkins, J. (1978) Using pictures in non-formal education. *Educational Broadcasting International* 11:32–38. [rJBD]
Jerison, H. J. (1967) Apparent motion of a vista: An illusion of perspective. *American Journal of Psychology* 80:448–53. [arJBD]
Johansson, G. (1975) Visual motion perception. *Scientific American* 232:76–88. [DR]
Johnson, M. (1987) *The body in the mind*. University of Chicago Press. [CSP]
Jones, R. K. & Hagen, M. A. (1980) A perspective on cross-cultural picture perception. In: *The perception of pictures*, vol. 2, ed. M. A. Hagen. Academic Press. [aJBD]
Julesz, B. (1971) *Foundations of Cyclopean perception*. University of Chicago Press. [rJBD, RHD]
Kagan, J. (1966) Reflection-impulsivity: The generality and dynamics of conceptual tempo. *Journal of Abnormal Psychology* 71:17–24. [aJBD]
Kant, I. (1781) *Critik der reinen Vernunft*. Hartknoch. [DR]
Kearins, J. M. (1976) Skills of desert Aboriginal children. In: *Aboriginal cognition*, ed. G. E. Kearney & D. W. McElwain. Australian Institute of Aboriginal Studies, Canberra. [aJBD]
(1981) Visual spatial memory in Australian Aboriginal children of desert regions. *Cognitive Psychology* 13:434–60. [rJBD, SCH]
Kellman, P. J. (1988) Theories of perception and research in perceptual development. In: *Perceptual development in infancy*, ed. A. Yonas. Erlbaum. [DWS]
Kelton, J. J., Holmes, S. R. & Pollack, R. H. (1978) Visual acuity for single lines as a function of hue and age. *Child Development* 49:141–45. [RHP]
Kennedy, J. M. (1974) *Psychology of picture perception*. Jossey-Bass. [aJBD, EBT]
(1975) Drawings were discovered, not invented. *New Scientist* 67:523–27. [rJBD]
(1982) Metaphor in pictures. *Perception* 11:589–605. [rJBD, JC-P]
(1983) What can we learn about pictures from the blind? *American Scientist* 71:19–26. [JMK]
(1987) Lo, perception abhors not a contradiction. In: *Illusory contours*, ed. S. Petry & G. E. Meyer. Springer-Verlag. [JMK]
Kennedy, J. M. & Ross, A. S. (1975) Outline picture perception by the Songe of Papua. *Perception* 4:391–406. [arJBD, IB]
Kidd, D. (1905) *The essential Kaffir*. A. & C. Black. [aJBD]
Kinnear, R. P. & Wood, M. (1987) Memory for topographic contour maps. *British Journal of Psychology* 78:395–402. [rJBD]
Kitcher, P. (1987) Discovering the forms of intuition. *Philosophical Reviews* 96:205–48. [DR]
Klapper, Z. S. & Birch, H. G. (1969) Perceptual and action equivalence of photographs in children. *Perceptual and Motor Skills* 29:763–71. [rJBD]
Klich, L. Z. & Davidson, G. R. (1983) A cultural difference in visual memory: On le voit, on ne le voit plus. *International Journal of Psychology* 18:189–201. [aJBD]
Kosslyn, S. M. (1980) *Image and mind*. Harvard University Press. [TLH]
(1981) The medium and the message in mental imagery: A theory. *Psychological Review* 88:46–66. [TLH]
(1982) *Ghosts in the mind's machine: Creating and using images in the brain*. Norton. [aJBD]
Kruskal, J. B. & Wish, M. (1978) *Multidimensional scaling*. Sage. [DMW]
Kulpa, Z. (1983) Are impossible figures possible? *Signal Processing* 5:201–20. [aJBD]
(1987) Putting order in the impossible. *Perception* 16:201–14. [arJBD]
Kus, S. (1979) Archaeology and ideology: The symbolic organization of space. Ph.D dissertation, University of Michigan. [CSP]
Landau, B. (1986) Early map use as an unlearned ability. *Cognition* 22:201–23. [RMD]
Landor, A. H. S. (1883) *Alone with the hairy Ainu or 3800 miles on a pack saddle in Yezo and a cruise to the Kurile Islands*. John Murray. [aJBD]
Laws, R. (1886) *Women's work in heathen lands*. Parlane. [aJBD]
(1901) In: *Geography and atlas of Protestant missions*, ed. H. P. Beach. Student Volunteer Movement for Foreign Missions. Quoted by Deregowski, Muldrow & Muldrow, 1972. [HM]
Leach, M. L. (1975) The effect of training in the pictorial depth perception of

Shona children. *Journal of Cross-Cultural Psychology* 6:457–70. [rJBD]

Leibowitz, H., Brislin, R., Perlmutter, L. & Hennessy, R. (1969) Ponzo perspective as a manifestation of space perception. *Science* 166:1174–76. [arJBD, RHP]

Leibowitz, H. & Pick, H. A. (1972) Cross-cultural and educational aspects of the Ponzo perspective illusion. *Perception and Psychophysics* 12:430–32. [aJBD]

Leroi-Gourhan, A. (1965) *Treasures of Prehistoric art.* Abrams. [CSP]

(1982) *The dawn of European art.* Cambridge University Press. [CSP]

Liben, L. S. & Downs, R. M. (1986) *Children's production and comprehension of maps: Increasing graphic literacy.* Final report to the National Institute of Education (G-83-0025). Pennsylvania State University. [NHF]

(in press) Understanding maps as symbols: The development of map concepts in children. In: *Advances in child development and Behavior,* vol. 21, ed. H. W. Reese. Academic Press. [RMD]

Liddell, C. (1986) The pre-school environment of township and Bushman children in Southern Africa. Paper presented at International Conference on Montessori Principles, Johannesburg. [rJBD]

Light, P. (1985) The development of view-specific representation considered from a socio-cognitive viewpoint. In: *Visual order: The nature and development of pictorial representation,* ed. N. H. Freeman & M. V. Cox. Cambridge University Press. [NHF]

Lissauer, H. (1890) Ein Fall von Seelenblindheit nebst einem Beitrage zur Theorie derseiben. *Archiv für Psychiatrie und Nervenkrankheiten* 27:222–70. [HDE]

Livingstone, D. (1857) *Missionary travels and researches in South Africa.* Murray. [arJBD]

Livingstone, M. S. & Hubel, D. H. (1987) Psychophysical evidence for separate channels for the perception of form, color, movement, and depth. *Journal of Neuroscience* 7:3416–68. [PW]

Lloyd, A. B. (1904) Acholi country, Part 2. *Uganda Notes* 5:18–22. [aJBD, ACD]

Luria, A. R. (1973) *The working brain.* Penguin. [aJBD]

Maffei, L. & Fiorentini, A. (1976) Monocular deprivation in kittens impairs the spatial resolution of geniculate neurones. *Nature* (London) 264:754–55. [RAW]

Makanju, O. O. A. (1976) Comparative study of comprehension of pictures in two Nigerian schools. Magisterial thesis, University of Aberdeen. [aJBD]

Mandler, J. M. & Parker, R. E. (1976) Memory for descriptive and spatial information in complex pictures. *Journal of Experimental Psychology: Human Learning and Memory* 2:38–48. [SCH]

Mariott, B. M. (1976) Picture perception and recognition in squirrel monkeys (*Samiri sciurens*). Ph.D. thesis, University of Aberdeen. [aJBD]

Marks, S. K. (1976) *Large mammals and a brave people.* University of Washington Press. [rJBD]

Marr, D. (1982) *Vision.* W. H. Freeman. [HDE]

Marr, D. & Nishihara, H. K. (1978) Representation and recognition of the spatial organization of three-dimensional shapes. *Proceedings of the Royal Society of London, Series B* 200:269–94. [DR]

Marshak, A. (1985) *Hierarchical evolution of the human capacity: The Paleolithic evidence.* American Museum of Natural History. [CSP]

Masterton, B. & Kennedy, J. M. (1975) Building the devil's tuning fork. *Perception* 4:107–9. [rJBD]

Maurer, D. & Salapatek, P. (1976) Developmental changes in the scanning of faces by young infants. *Child Development* 47:523–27. [rJBD, SCH]

McFie, J. (1961) The effect of education of African performance on a group of intellectual tests. *British Journal of Educational Psychology* 31:232–40. [aJBD]

McGurk, M. & Jahoda, G. (1975) Pictorial depth perception by children in Scotland and Ghana. *Journal of Cross-cultural Psychology* 6:279–96. [aJBD]

Meneghini, K. A. & Leibowitz, H. W. (1967) Effect of stimulus distance and shape or shape constancy. *Journal of Experimental Psychology* 74:241–48. [aJBD]

Miller, R. J. (1973) Cross-cultural research in the perception of pictorial materials. *Psychological Bulletin* 80:135–50. [NHF]

Mitchell, D. E. (1979) Astigmatism and neural development. *Investigative Ophthalmology & Visual Science* 18:8–10. [RAW]

Mitchell, N. B. & Pollack, R. H. (1974) Block-design performance as a function of hue and race. *Journal of Experimental Child Psychology* 17:377–82. [RHP]

Mitchell, N. B., Pollack, R. H. & McGrew, J. F. (1977) The relation of form perception to hue and fundus pigmentation. *Bulletin of the Psychonomic Society* 9:97–99. [RHP]

Mitchelmore, M. C. (1978) Developmental stages in children's representation of regular solid figures. *Journal of Genetic Psychology* 133:229–40. [aJBD]

(1980a) Predictions of developmental stages in representation of regular space figures. *Journal for Research in Mathematics Education* 11:83–93. [aJBD]

(1980b) Three-dimensional geometrical drawings in three cultures. *Educational Studies in Mathematics* 11:205–16. [aJBD]

(1987) Why do children not use parallels in their drawings of cubes? *Archives de Psychologie* 55:179–94. [JC-P]

Mooney, C. M. (1954) Age in the development of closure ability in children. *Canadian Journal of Psychology* 11:219–26. [JMK]

Morris, R. G. M. (1981) Spatial localization does not require the presence of local cues. *Learning and Motivation* 12:239–60. [DMW]

Moyer, R. S., Bradley, D. R., Sorenson, M. H., Whiting, J. C. & Mansfield, D. P. (1978) Psychophysical functions for perceived and remembered size. *Science* 200:330–32. [TLH]

Mundy-Castle, A. C. & Nelson, G. K. (1962) A neuropsychological study of the Knysna forest workers. *Psychologia Africana* 9:240–72. [aJBD]

Munn, N. (1986) *Walbiri iconography,* 2nd ed. University of Chicago Press. [rJBD, CSP]

Murray, F. S. & Szymczyk, J. M. (1978) Effects of distinctive features on the recognition of incomplete pictures. *Developmental Psychology* 14:356–62. [rJBD]

Myambo, K. (1972) Shape constancy as influenced by culture, Western education, and age. *Journal of Cross-cultural Psychology* 3:221–31. [aJBD]

Nadel, S. F. (1937a) A field experiment in racial psychology. *British Journal of Psychology* 28:195–211. [rJBD]

(1937b) Experiments of culture psychology. *Africa* 10:412–35. [rJBD]

(1937c) The typological approach to culture. *Character and Personality* 5:267–83. [rJBD]

(1939/1946) The application of intelligence tests in the anthropological field. In: *The study of society: Methods and problems,* ed. F. C. Bartlett, M. Ginsberg, E. J. Linkgren & R. H. Thouless. Kegan Paul, Trench, Trubues. [aJBD]

Newman, C. V. (1969) Children's size judgements in a picture with suggested depth. *Nature* 223:418–20. [aJBD]

Nicholson, J. R. & Seddon, G. M. (1977) Understanding of pictorial spatial relationships by Nigerian secondary school students. *Journal of Cross-cultural Psychology* 8:381–400. [arJBD, DWS]

Nicholson, J. R., Seddon, G. M. & Worsnop, J. G. (1977) Teaching understanding of pictorial spatial relationships to Nigerian secondary school students. *Journal of Cross-cultural Psychology* 8:401–14. [aJBD]

Nissen, H. W., Machover, S. & Kinder, E. F. (1935) A study of performance tests given to group of native African Negro children. *British Journal of Psychology* 25:308–55. [aJBD]

Opolot, J. A. (1976) Differential cognitive cues in pictorial depth perception in Ugandan children. *International Journal of Psychology* 11:81–88. [aJBD]

Page, H. W. (1970) Pictorial depth perception: A note. *South African Journal of Psychology* 1:45–48. [aJBD]

Pedersen, D. M, & Wheeler, J. (1983) The Müller–Lyer illusion among Navajos. *Journal of Social Psychology* 121:3–6. [DFH]

Perkins, D. N. (1972) Visual discrimination between rectangular and non-rectangular parallelepipeds. *Perception and Psychophysics* 12:396–400. [aJBD]

Perkins, D. N. & Deregowski, J. B. (1982) A cross-cultural comparison of the use of a Gestalt perceptual strategy. *Perception* 11:279–86. [arJBD, IB]

Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D. & Jeeves, M. A. (1985) Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Royal Society of London Series B* 223:293–317. [PW]

Perry, M. D. & Wolf, D. (1986) Mapping symbolic development. Paper presented at the Sixteenth Annual Symposium of the Jean Piaget Society, Philadelphia. [RMD]

Petermann, B. (1932) *The Gestalt theory and the problem of configuration.* Harcourt, Brace. [aJBD]

Piaget, J. & Inhelder, B. (1956) *The child's conception of space.* Routledge and Kegan Paul. [aJBD]

Pickford, R. W. (1972) *Psychology and visual aesthetics.* Hutchinson. [aJBD]

Piotrowski, Z. (1935) Racial differences in linear perspective. *Journal of Social Psychology* 6:479–85. [aJBD]

Pirenne, M. H. (1952) The scientific basis of Leonardo da Vinci's theory of perspective. *British Journal for the Philosophy of Science* 3:169–85. [EBT]

(1970) *Optics, painting and photography.* Cambridge University Press. [arJBD, EBT]

(1975) Vision and art. In: *Handbook of perception*, vol. 5, ed. E. C. Carterette & M. P. Friedman. Academic Press. [EBT]

Polanyi, M. (1958) *Personal knowledge: Towards a post-critical philosophy.* Routledge and Kegan Paul. [aJBD]

(1970) What is painting? *British Journal of Aesthetics* 10:225–36. [arJBD]

Pollack, R. H. (1963) Contour detectability thresholds as a function of chronological age. *Perceptual and Motor Skills* 17:411–17. [RHP]

(1965) Hue detectability thresholds as a function of chronological age. *Psychonomic Science* 3:351–52. [RHP]

(1969) Some applications of ontogenetic changes in perception. In: *Studies in cognitive development: Essays in honor of Jean Piaget*, ed. B. Elkind & J. H. Flavell. Oxford University Press. [RHP]

(1970a) Mueller–Lyer illusion: Effect of age, lightness contrast and hue. *Science* 170:93–95. [RHP]

(1970b) Magnitude of the Mueller–Lyer illusion as a function of hue in the absence of lightness contrast. *Proceedings of the 78th Annual Meeting of the American Psychology Association.* [RHP]

(1972) Perceptual development: A progress report. In: *Information processing in children*, ed. S. Farnham-Diggory. Academic Press. [RHP]

(1976) Illusions and perceptual development: A tachistoscopic psychological approach. In: *The developing individual in a changing world*, ed. K. F. Rigel & J. A. Mecham. Mouton. [RHP]

Pollack, R. H. & Silvar, S. D. (1967a) Magnitude of the Mueller–Lyer illusion in children as a function of pigmentation of the fundus oculi. *Psychonomic Science* 8:83–84. [rJBD, SC, RHP]

(1967b) Racial differences in the pigmentation of the fundus oculi. *Psychonomic Science* 7:159–60. [rJBD, SC]

Preziosi, D. (1979) *The semiotics of the built environment.* Indiana University Press. [CSP]

Rabardel, P. & Weill-Fassina, N. (1987) *Le dessin technique.* Hermes. [rJBD]

Ramkissoon, R. D. & Bhana, K. (1982) Effects of stimulus variable on matrix classification responses of 12-year-old children. *South African Journal of Psychology* 12:101–5. [aJBD]

Reuning, H. & Wortley, W. (1973) Psychological studies of the Bushmen. *Psychologia Africana Monograph Supplement No. 7.* [aJBD, FJRV]

Riddoch, M. J. & Humphreys, G. W. (1986) Neurological impairments of object constancy: The effects of orientation and size disparities. *Cognitive Neuropsychology* 3:207–24. [NHF]

Rivers, W. H. R. (1901) Vision. In: *Reports of the Cambridge anthropological expedition to Torres Straits*, ed. W. H. R. Rivers. Cambridge University Press. [aJBD]

(1905) Observations on the senses of the Todas. *British Journal of Psychology* 1:321–96. [aJBD]

Roberts, W. A. (1984) Some issues in animal spatial memory. In: *Animal cognition*, ed. H. L. Roitblat, T. G. Bever & H. S. Terrace. Erlbaum. [DMW]

Robinson, J. O. (1972) *The psychology of visual illusions.* Hutchinson. [arJBD, JMK]

Rock, I., Halper, F. & Clayton, C. (1972) The perception and recognition of complex figures. *Cognitive Psychology* 3:655–73. [IB]

Rubin, E. (1915) *Visuell wahregenommene Figuren.* Gyldendal. [AJBD]

Schier, F. (1986) *Deeper into pictures: An essay on pictorial representation.* Cambridge University Press. [rJBD, HDE, NHF]

Schiller, P. & Weiner, M. (1962) Binocular and streoscopic viewing of geometrical illusions. *Perceptual and Motor Skills* 15:739–47. [rJBD]

Seddon, G. M. (1985) Developmental trends in the ability of primary school children to construct models from diagrams. *Educational Psychology* 5:55–64. [aJBD]

Seddon, G. M., Einaiyeju, P. A. & Jusho, I. (1984) The visualisation of rotation in diagrams of three-dimensional structure. *American Educational Research Journal* 21:25–38. [arJBD]

Seddon, G. M., Tariq, R. H. & Dos Santos Veiga, J. (1984) The transferability of two pictorial scientific tasks between different spatial dimensions. *British Journal of Educational Psychology* 54:276–83. [arJBD]

Segall, M. H. (1979) *Cross-cultural psychology.* Brooks/Cole. [aJBD]

Segall, M. H., Campbell, D. T. & Herskovits, J. M. (1963) Differences in perception of geometric illusions. *Science* 139:769–71. [aJBD, GJ]

(1966) *Influence of culture on visual perception.* Bobbs-Merill. [arJBD, JE, GJ, RHP, DWS, FJRV]

Senden, M. von (1960) *Space and sight.* Free Press. [TI]

Serpell, R. (1974) Can pictures teach? *Science and Education in Zambia* 5:11–18. [aJBD]

(1979) How specific are perceptual skills? A cross-cultural study of pattern reproduction. *British Journal of Psychology* 70:365–80. [aJBD]

(1985) Hoe specifiek zijn de psychologische factoren die ten grondslag liggen aan inter-culturele verschillen in gedrag? In: *Verkenningen in de cross-culturele psychologie*, ed. J. M. H. Van de Koppel. Swets & Zeitlinger. [aJBD]

Serpell, R. & Deregowski, J. B. (1972) *Teaching pictorial depth perception – a classroom experience.* University of Zambia HDRU Report. [rJBD]

(1980) The skill of pictorial perception: An interpretation of cross-cultural evidence. *International Journal of Psychology* 15:145–80. [arJBD, FJRV]

Shapiro, M. B. (1960) The rotation of drawings by illiterate Africans. *Journal of Social Psychology* 52:17–30. [aJBD]

Shaw, B. (1969) *Visual symbols survey.* Centre for Educational Development Overseas, London. [aJBD]

Shepherd, J. (1981) Social factors in face recognition. In: *Perceiving and remembering faces*, ed. G. Davies, H. Ellis & J. Shepherd. Academic Press. [aJBD]

(1983) Faces in cross-cultural perspective. In: *Expiscations in cross-cultural psychology*, ed. J. B. Deregowski, S. Dziurawiec & R. C. Annis. Swets & Zeitlinger. [aJBD]

Shepard, R. N. & Metzler, J. (1971) Mental rotation of three-dimensional objects. *Science* 171:701–3. [rJBD, DP]

Shepard, R. N. & Podgorny, P. (1978) Cognitive processes that resemble perceptual processes. In: *Handbook of learning and cognitive processes*, vol. 5, ed. W. K. Estes. Erlbaum. [TLH]

Sherry, D. F. (1984) What food-storing birds remember. *Canadian Journal of Psychology* 38:304–21. [DMW]

Sidman, M. (1960) *Tactics of scientific research: Evaluating experimental data in psychology.* Basic Books. [DMW]

Sigel, I. E. (1968) The distancing hypothesis: A causal hypothesis for the acquisition of representational thought. Paper delivered at University of Miami symposium on The Effects of Early Experience. [arJBD, TLH]

(1978) The development of pictorial comprehension. In: *Visual learning, thinking and communication*, ed. B. S. Randhawa & W. E. Coffman. Academic Press. [aJBD]

Silvar, S. & Pollack, R. H. (1967) Racial differences in pigmentation of the fundus oculi. *Psychonomic Science* 7:159–60. [rJBD, RHP]

Sjostrom, K. P. & Pollack, R. H. (1971a) The effect of simulated receptor aging on two types of visual illusions. *Psychonomic Science* 23:147–48. [RHP]

(1971b) Simulated receptor in the study of ontogenetic trends of visual illusions. *Proceedings of the 79th Annual Meeting of the American Psychological Association.* [RHP]

Skoff, E. & Pollack, R. H. (1969) Visual acuity in children as a function of hue. *Perception & Psychophysics* 6:244–46. [RHP]

Smith, O. W. & Smith, P. C. (1962) An illusion of parallelism. *Perceptual and Motor Skills* 15:455–61. [aJBD]

Spelke, E. S. (1988) Where perceiving ends and thinking begins: The apprehension of objects in infancy. In: *Perceptual development in infancy*, ed. A. Yonas. Erlbaum. [DWS]

Spencer, J. (1965) Experiments in engineering drawing comprehension. *Ergonomics* 8:93–110. [aJBD]

Sternberg, R. J. (1980) Sketch of a componential subtheory of human intelligence. *Behavioral and Brain Sciences* 3:573–84. [FJRV]

Stevens, A. & Coupe, P. (1978) Distortions in judged spatial relations. *Cognitive Psychology* 10:422–37. [SCH]

Stewart, M. V. (1973) Tests of the "carpentered world" hypothesis by race and environment in America and Zambia. *International Journal of Psychology* 8:83–94. [aJBD]

Street, R. F. (1931) Gestalt completion test. *Teachers' College contributions to education.* [JMK]

Strzeminski, W. (1974) *Teoria Widzenia.* Wydawnictwo Literackie Krakow. [aJBD]

Sutherland, R. J. & Dyck, R. H. (1984) Place navigation by rats in a swimming pool. *Canadian Journal of Psychology* 38:322–47. [DMW]

Taylor, H. R. (1981) Racial variations in vision. *American Journal of Epidemiology* 113:62–80. [SC]

Taylor, T. R. (1974) A factor-analysis of 21 illusions: The implications for theory. *Psychologia Africana* 15:137–47. [arJBD]

(1976) The factor structure of geometric illusions: A second study. *Psychologia Africana* 16:177–200. [arJBD]

ten Doesschate, G. (1964) *Perspective, fundamentals, controversials, history.* B. De Graff, Nieuwkoop. [arJBD]

ten Doesschate, G. & Klystra, J. (1955) The perception of parallels. *Aeromedica* 4:115–19. [aJBD]

Thomas, L. F. (1962) Perceptual organisation of industrial inspectors. *Ergonomics* 5:429–34. [rJBD]

Thomson, J. (1885) *Through Masailand: A Journey of exploration.* Sampson Low, Marston, Searle and Rivington. [aJBD]

Thorndyke, P. W. & Stasz, C. (1980) Individual differences in procedures for

knowledge acquisition from maps. *Cognitive Psychology* 12:137–75. [rJBD]
Thouless, R. H. (1933) A racial difference in perception. *Journal of Social Psychology* 4:330–39. [aJBD]
Thro, E. B. (1983) Distinguishing two classes of impossible objects. *Perception* 12:722–51. [EBT]
Timney, B. N. & Muir, D. K. (1976) Orientation anisotrophy: Incidence and magnitude in Caucasian and Chinese subjects. *Science* 193:699–701. [rJBD, RAW]
Topper, D. R. (1979) Further reflections on J. J. Gibson's hypothesis of picture perception. *Leonardo* 12:135–36. [aJBD]
Tsafrir, J. S. (1974) *Light eyed Negroes and the Klein-Waardenburg syndrome.* Macmillan. [rJBD]
Turnbull, C. M. (1962) *The forest people.* Simon and Schuster. [TLH]
Turton, D. (1980) There's no such beast: Cattle and colour naming among the Mursi. *Man* 15:320–38. [rJBD]
Van Beusekom, G. (1948) Some experiments on the optical orientation in Philanthus Triangulum Fabr. *Behaviour* 1:195–233. [DMW]
Van de Koppel, J. M. H. (1983) *A developmental study of the Biaka Pygmies and the Baganda.* Swets and Zeitlinger. [aJBD]
von Fieandt, K. & Moustgaard, I. K. (1977) *The perceptual world.* Academic Press. [aJBD]
Vurpillot, E. (1963) *L'organisation perceptive.* Librarie Philosophique J. Vrin. [rJBD]
Wald, G. (1945) Human vision and the spectrum. *Science* 101:653–58. [RHP]
Wallach, H. & O'Connell, D. N. (1953) The kinetic depth effect. *Journal of Experiemental Psychology* 45:205–17. [RHD]
Ward, L. M. & Coren, S. (1976) The effect of optically-induced blur on the magnitude of the Mueller–Lyer illusion. *Bulletin of the Psychonomic Society* 7:483–84. [SC]
Warrington, E. K. & James, M. (1986) Visual object recognition in patients with right-hemisphere lesions: Axes or features? *Perception* 15:355–66. [DR]
Weale, R. A. (1968) *From sight to light.* Oliver & Boyd. [rJBD]
(1978) Experiments on the Zollner and related optical illusions. *Vision Research* 18:203–8. [RAW]
(1979) Discoverers of Mach bands. *Investigative Ophthalmology and Visual Science* 18:652–54. [rJBD]
(1982a) *A biography of the eye – development, growth, age.* H. K. Lewis. [rJBD RAW]
(1982b) *Focus on vision.* Hodder & Stoughton. [RAW]
Welford, A. T. (1970) *Fundamentals of skill.* Methuen. [rJBD]
Werner, H . (1948) *Comparative psychology of mental development.* International Universities Press. [rJBD]
Wilkie, D. M. (1987) A multidimensional scaling analysis of pigeons' representation of two-dimensional space. Paper presented at the 2nd Spring Conference on Behaviour and Brain. Banff, Canada. [DMW]
(in press) Evidence that pigeons represent Euclidean properties of space. *Journal of Experimental Psychology: Animal Behavior Processes.* [DMW]
Wilkie, D. M . & Summers, R. J. (1982) Pigeons' spatial memory: Factors affecting delayed matching of key locations. *Journal of Experimental Analysis of Behavior* 37:45–56. [DMW]
Willats, J. (1984) Getting the drawing to look right as well as to be right: The interaction between production and perception as a mechanism of development. In: *Cognitive processes in the perception of art*, ed. W. R. Crozier & A. J. Chapman. North-Holland. [JC-P]
(1987) Marr and pictures: An information-processing account of children's drawings. *Archives de Psychologie* 55:105–25. [NHF]
Wilson, B. G. & Wilson, M. (1984) Children's drawings in Egypt: Cultural style acquisition as graphic development. *Visual Arts Research* 10:14–21. [NHF]
Wilson, M. & Wilson, B. G. (1982) The case of the disappearing two-eyed profile: Or how little children influence the drawings of little children. *Review of Research in Visual Arts Education* 8:1–8. [NHF]
Winter, W. (1963) The perception of safety posters by Bantu industrial workers. *Psychologia Africana* 10:127–35. [arJBD]
(1967) Size constancy, relative size estimation and background: A cross-cultural study. *Psychologia Africana* 12:42–48. [aJBD]
Witkin, M. A. (1962) *Psychological differentiation: Studies of development.* Wiley. [aJBD]
Witkin, M. A. & Berry, J. W. (1975) Psychological differentiation in cross-cultural perspective. *Journal of Cross-cultural Psychology* 6:4–78. [aJBD]
Witkin, M. A. & Goodenough, D. R. (1977) Field dependence and interpersonal behaviour. *Psychological Bulletin* 84:661–89. [aJBD]
Wittgenstein, L. (1958) *Philosophical investigations*, 3rd ed. Trans. G. E. M. Anscombe. Macmillan. [EBT]
Wolf, D. & Gardner, H. (1985) *Broadening literacy: A final report to the Carnegie Corporation.* Harvard Graduate School of Education. [RMD]
Wood, D. (1977) Now and then: Comparisons of ordinary American's symbol conventions with those of past cartographers. *Prologue* 1977:151–61. [RMD]
Woodruff, M. E. & Samek, M. J. (1976) The refractive status of Belcher Island Eskimos. *Canadian Journal of Public Health* 67:314–20. [SC]
Wyburn, G. M., Pickford, R. W. & Hirst, R. J. (1964) *Human senses and perception.* Oliver & Boyd. [arJBD]
Yonas, A., Arterberry, M. E. & Granrud, C. E. (1987) Space perception in infancy. In: *Annals of Child Development* 4:1–34. JAI Press. [PW]
Yonas, A., Cleaves, W. & Pettersen, L. (1978) Development of sensitivity to pictorial depth. *Science* 200:77–79. [rJBD]
Youn, G., Lambert, A. M. & Pollack, R. H. (1987) The life-span trend in the magnitude of the Mueller–Lyer illusion as a function of hue and age. *Experimental Aging Research* 13:53–56. [RHP]
Youn, G. & Pollack, R. H. (submitted) The magnitude of the Mueller–Lyer illusion as a function of hue, saturation, fundus pigmentation, and simulated aging. [RHP]
Young, A. & Deregowski, J. B. (1981) Learning to see the impossible. *Perception* 10:91–105. [arJBD, EBT]
Zajac, J. L. (1961) Studies in perspective. *British Journal of Psychology* 59:333–40. [arJBD]