PERCEPTION OF DEPTH IN DRAWINGS:
A DEVELOPMENTAL STUDY OF
YOUNG MALAWIANS

by.

JUDITH IRESON
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of figures</td>
<td>iv</td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>vi</td>
</tr>
<tr>
<td>Chapter One</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>The conventions of art</td>
<td>3</td>
</tr>
<tr>
<td>Recognition of objects in drawings and photographs</td>
<td>7</td>
</tr>
<tr>
<td>Identification and interpretation of more complex outline drawings</td>
<td>19</td>
</tr>
<tr>
<td>Chapter Two</td>
<td>24</td>
</tr>
<tr>
<td>Perception of depth in pictures</td>
<td>24</td>
</tr>
<tr>
<td>Information for flatness and depth in a picture</td>
<td>24</td>
</tr>
<tr>
<td>Perception of depth in pictures by Western adults</td>
<td>30</td>
</tr>
<tr>
<td>The development of pictorial depth perception</td>
<td>33</td>
</tr>
<tr>
<td>in Western children</td>
<td>33</td>
</tr>
<tr>
<td>Cross-cultural assessment of pictorial depth perception</td>
<td>45</td>
</tr>
<tr>
<td>Summary</td>
<td>61</td>
</tr>
<tr>
<td>Chapter Three</td>
<td>64</td>
</tr>
<tr>
<td>Constancy effects with objects and pictures</td>
<td>64</td>
</tr>
<tr>
<td>Size and shape constancy</td>
<td>64</td>
</tr>
<tr>
<td>Cross-cultural studies of size and shape constancy</td>
<td>68</td>
</tr>
<tr>
<td>Size constancy in drawings and photographs</td>
<td>72</td>
</tr>
<tr>
<td>Implicit-shape constancy</td>
<td>76</td>
</tr>
<tr>
<td>Summary</td>
<td>79</td>
</tr>
</tbody>
</table>
Chapter Four
Experiment 1
Experiment 2
Experiment 3
Discussion
Chapter Five
Introduction
Experiment 4
Experiment 5
Experiment 6
Experiment 7
Experiment 8
Chapter Six
Introduction and experiment 9
Discussion
Chapter Seven
Summary of results
Discussion
  a. Contrast of the Hudson method with the
     Jahoda-McGurk method
  b. Spatial development
  c. The relative efficacy of pictorial depth cues
  d. The role of familiarity in recognition and
     the perception of pictorial depth
  e. Pictorial convention versus photographic
     projection
  f. The development of strategies for the
     interpretation of pictorial depth

ii
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>From Shaw, 1969, p.10</td>
<td>12</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Examples of pictures from Jahoda and McGurk 1974c, p 261</td>
<td>55a</td>
</tr>
<tr>
<td>Figure 3</td>
<td>From Deregowski, 1976b</td>
<td>78</td>
</tr>
<tr>
<td>Figure 4</td>
<td>From Hudson, 1960</td>
<td>87</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Cards 1 and 2</td>
<td>88a</td>
</tr>
<tr>
<td></td>
<td>Cards 3 and 4</td>
<td>88b</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Graph of percentages of 3D responses to cards 1 and 2 by age and sex</td>
<td>94a</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Modified stance pictures</td>
<td>103a</td>
</tr>
<tr>
<td>Figure 7b</td>
<td>Card 2 with orientation criteria marked</td>
<td>106a</td>
</tr>
<tr>
<td></td>
<td>Cards 3 and 4 with orientation criteria</td>
<td>106b</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Examples of huts pictures</td>
<td>116a</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Diagram of apparatus</td>
<td>120a</td>
</tr>
<tr>
<td>Figure 10</td>
<td>One example of each series of huts pictures having the less elevated rearground hut</td>
<td>127a</td>
</tr>
<tr>
<td>Figure 11</td>
<td>One example of each of the four adult-child combinations</td>
<td>133a</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Examples of pictures from Jahoda and McGurk 1974c, p 261</td>
<td>136a</td>
</tr>
<tr>
<td>Figure 13</td>
<td>From McGurk and Jahoda 1975, p 284</td>
<td>136a</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Photographs of all combinations of the Lactogen tins</td>
<td>138a</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Examples of arrangements of objects in experiment 9</td>
<td>147a</td>
</tr>
</tbody>
</table>
Abstract

This dissertation reports a series of 9 experiments designed to investigate pictorial depth perception in Malawian children and young adults. It was found that familiarity of depicted material was a significant factor influencing subjects' interpretation of the spatial relationships in pictorial scenes and that both educated and uneducated children displayed an ability to interpret distance relationships in pictures having familiar content. In general, perception of pictorially depicted size and spatial relationships increased in accuracy with age, but spatial accuracy increased much more sharply than accuracy of size judgements, and was more strongly associated with subjects' educational background. Rather little differential sensitivity was displayed to individual depth cues aside from interposition, and it was proposed that this was because monocular cues were not salient in subjects' judgements of depth in three-dimensional scenes. In addition to familiarity, accuracy of size judgements was also influenced by the presence or absence of cues for flatness of the picture plane. The results are discussed in relation to other empirical studies and in terms of their significance for different theoretical approaches to pictorial depth perception. Consideration is also given to the implications of the findings for the use of black-and-white drawings as didactic tools, and for the development of training procedures to enhance pictorial depth perception.
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CHAPTER ONE

Introduction

Many thousands of years ago, a startling discovery was made, the discovery of representation. Scratching and making grooves, daubing and shaping began to be used for a new purpose, the making of images. Gradually cave art developed, with the use of pigments applied to the cave surfaces. Since then, the making of images has proliferated with different artistic styles emerging all over the world. In the West, the discovery of pictorial perspective during the Renaissance gave a fresh impetus to representational painting.

The Renaissance painters began to apply the emerging concepts of light rays to the making of representational pictures. And instead of thinking of a picture as an object with surface markings, they thought of it as a window. The artist could place a sheet of glass between himself and his subject and copy the subject onto the glass. The viewer then looked at the painted glass framed like a window and he gained the impression that he was looking out of a window at a real scene. This immediately opened up the exciting possibility of representing three-dimensionality in a convincing way, and the challenge then became that of doing it so well as to fool observers into thinking they viewed a
real scene when looking at the picture. In order to achieve this effect, the laws of perspective had to be carefully applied. These were first described by Leonardo da Vinci (1452-1519) in his Notebooks, where he treated perspective as a branch of geometry. He described how a perspective could be drawn directly on a sheet of glass, and included a treatment of other perspective effects such as increasing haze and blueness with increasing distance, and the importance of shadows and shading to represent the orientation of objects. The technique of linear perspective was developed by architects for the representation of buildings, but in order to represent people and light and shadow, the perspective of reflectance and illumination has also to be included.

One of the greatest examples of a perspective painting is Fra. Andrea Pozzo's ceiling of the Church of St. Ignatius in Rome (see Pirenne, 1970 Ch. 7). If the ceiling is viewed from the correct station point, the impression of three-dimensionality is compelling, and the figures appear to be suspended, flying through the air. If the observer moves away from the correct station point, there is a marked loss of the perspective effect.

The most compelling impressions of depth are thus obtained by a central projection of the scene onto the picture surface, and the viewing of the picture from the central projection point, or correct station point. In fact, in many of the larger paintings, artists use more than
one centre of projection so that the centres remain approximately perpendicular to the canvas. This is easier for the artist, and it also serves to lessen distortion as the viewer moves along the painting. In a later section, some of the techniques used by the artist in order to achieve an impression of depth will be considered. For the moment, some theoretical issues will be raised and briefly discussed.

The conventions of art.

One very fundamental question which must be asked about pictures is to what extent they correspond to their referents. Was the development of perspective painting simply a matter of developing a set of conventions which could be understood by artist and viewer alike? Or was the artist learning something about geometrical relations and the behaviour of light which he could then use to convey information to the viewer? The first position is held by Goodman (1968) when he states that "Realism is relative, determined by the system of representation standard for a given culture or person at a given time." He goes on to contend that "Representational customs... also tend to generate resemblance. That a picture looks like nature often means only that it looks the way nature is usually painted." And he adds the remark made by Picasso on being told that his painting of Gertrude Stein did not resemble her - the
painter's reply was "No matter, it will".

In opposition to Goodman's view is that of Gibson who stated that "...it does not seem reasonable to assert that the use of perspective in paintings is merely a convention, to be used or discarded by the painter as he chooses" (1960, p.227). Gibson contends that "A picture is a surface so treated that a delimited optic array to a point of observation is made available that contains the same kind of information that is found in the ambient optic arrays of an ordinary environment" (1971, p31). If this were true, then the observer would be able to pick up information from the picture similar to that normally in his environment, and he should therefore be able to do so without training in picture perception, as long as the pictures were of objects familiar to him.

Gibson acknowledges that experience contributes to perception:

"The perceiver who has observed the world from many points of view, as we say, is literally one who has travelled about and used his eyes. That is, he has looked at the furniture of the earth from many station points. The more he has done so, the more likely it is that he has isolated the invariant properties of things - the permanent residue of the changing perspectives " (Gibson 1960, p.220).

The view of Goodman, however, has been echoed by writers such as Hudson (1960) and Fuglesang (1972) who have found
cultural differences in response to test pictures and
ascribed the differences to a lack of assimilation of
Western artistic conventions. Fuglesang, for example,
contends that the details or parts of a picture form a
pictorial language and "that pictures cannot be used as
efficient means of communication unless the sender knows the
pictorial language himself and can apply it in expressing a
message and, above all, unless he knows what his audience
knows of the language".

As Gibson (1954) has pointed out, language and pictures
may correspond more or less to their referents. In general,
pictures correspond more closely than words, with
photographs and some paintings having greater correspondence
than outline drawings and cartoons. Gibson goes on to make
four propositions, two of which are particularly relevant
here. The first is that children have to learn the
correspondence of a surrogate to its object, and the more
nearly a surrogate is conventional, the more does
associative learning need to occur. The second is that the
introduction of graphic symbolisation into a picture
necessarily sacrifices its capacity to represent.

Thus a faithful picture, one that transmits or reflects
a sheaf of light rays to a given point which is the same as
would be the sheaf of rays from the original to that point,
should be readily apprehended by an observer. With
decreasing fidelity, the incidence of errors in recognition
would be expected. However, as will be seen later, the
situation is not quite as simple as this, for recognition of objects faithfully portrayed in photographs is dependent also on the subject's experience with the object.

In his later work, Gibson moves away from considering the fidelity of sheafs of light rays as of prime importance for conveying pictorial information. Instead, he proposes (Gibson 1973, 1979) "that invariants are information for perception, even in the special case of pictorially mediated perception" (1973, p.44). He goes on to say "A good picture does not have to be in point-to-point correspondence with the facing surfaces of an actual concrete world (although a picture can be just such a projection and a photograph is one)" (1973, p.44).

The amount of information varies, even in pictures that are in a point-to-point correspondence with a real scene. Thus, pictures of a human figure may range from the colour photograph against a neutral background through black-and-white photographs to outline drawings and silhouettes. All of these may contain accurate information, but some contain more than others. Where the information is scanty or conflicting, the observer relies increasingly on his knowledge of conventions to deduce the content. The interest then focuses on the picture, and the search for features which facilitate perception in different cultures. The empirical work reported herein will lend support to a position closer to Gibson than to Goodman.
Studies on the recognition of objects in drawings and photographs will be reviewed in this chapter. In Chapter Two, the recognition and interpretation of more complex drawings will be considered, and the literature on the perception of depth in pictures reviewed. The development of constancy and its relation to pictorial depth perception will be explored in Chapter Three.

Recognition of objects in drawings and photographs

As adults in a pictorially educated environment, there is a tendency to assume that objects and figures in drawings and photographs will be recognised by others. Cross-cultural studies put this assumption to question. Early reports by travellers, missionaries and scholars provided contradictory and largely anecdotal accounts of naive observers' reactions to photographs. Thus Herskovits (1959, p.56) describes how "... a bush Negro woman turned a photograph of her own son this way and that, in attempting to make sense out of the shadings of greys on the piece of paper she held. It was only when the details of the photograph were pointed out to her that she was able to perceive the subject. Laws (1901) made the following observation in Nyasaland: "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 a few 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! 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". On the other hand, Nadel (1937) found that Yoruba and Nupe people in Nigeria recognised photographs of men, animals and a bush fire; and Brimble (1963) reported good recognition of simple line drawings by Barotse men and women.

Segall et al. (1966) suggest that a photograph be considered as an arbitrary linguistic convention not shared by all peoples. Western viewers have learned to ignore the strongest contours of the photograph, which are its rectangular edges. Within these edges, the white band around the picture is the most striking part of the design. By comparison, the contours around the objects in the photograph are fuzzy and provide only weak contrasts. The authors attribute the difficulties in perceiving photographs to the lack of experience with them and hence a lack of familiarity with the conventions involved in their correct interpretation. This view may be partially correct, in that observers learn to ignore the strong frame contours, but work reported below suggests that recognition of objects in line drawings is not learned. Segall et al. also note that
anthropologists have generally reported motion pictures to be perceived without trouble, and that coloured prints are also.

The well-known study by Hochberg and Brooks (1962) shows that recognition of outline drawings of familiar objects does occur even without prior experience with pictures. They prevented their child from having anything but a minimal exposure to pictures, and gave him no opportunities for naming objects in pictures. After 19 months, the child was tested and was able to recognise outline drawings and photographs of objects such as a car, a shoe, a doll, a truck, a rocking horse, keys and a toy duck. In instances where an outline drawing and a photograph of the same object were shown, the outline drawing preceded the photograph. All the drawings contained sufficient detail to enable correct identification, but no more.

More recently, Dereqowski, Muldrow and Muldrow (1972) showed members of a remote Ethiopian tribe (the Mekan), a page from a children's colouring book. Most of the people were probably entirely unfamiliar with pictures, and appeared to pay no attention to the surface markings, instead their interest lay in the paper itself, and this they smelt, listened to while flexing and even tried to taste. However, when pictures of a buck and a leopard, which were well-known to the Mekan, were printed on coarse cloth, all the subjects recognised the leopard and almost all recognised the buck. Interestingly, though, the recognition
required time and effort, and the authors report the two following examples:

"1. Lowland man, 35 years old, looks at the picture:

   Experimenter: (Points to the picture): 'What do you see?'
   Subject: 'I'm looking closely. That is a tail. This is a foot. That is a leg joint. Those are horns.'
   E: 'What is the whole thing?'
   S: 'Wait. Slowly, I am still looking. Let me look and I will tell you. In my country this is a water-buck.'

2. Lowland man, 25 years old:

   E: (points to the picture): 'What do you see?'
   S: 'What is this? It has horns, leg .... front and back tail, eyes. Is it a goat? A sheep? Is it a goat?''

Deregowski (1976) postulates that the viewer is operating a process of successive approximations. He makes a hypothesis on the basis of a sample of the data available and verifies the hypothesis against another sample of data derived from the same source, the picture. He modifies the hypothesis if necessary and tests it against a further sample till no further modification is called for and a stable perception occurs. He further suggests that the more
complex process of perceiving depth in pictures may occur in this fashion and the viewer may be unable to verbalise it.

The attention to detail in the process of identification of pictures is well illustrated in a study of the recognition of line drawings carried out in Kenya (Shaw, 1969). Subjects were asked to identify drawings of a cow, goat, chicken, bird, cat, dog, fish, snake, crocodile, turtle and horse. On average, 70-80% of the rural illiterates gave the correct names. The snake was identified by almost 100%, whereas the horse, which is not indigenous, was recognised by only 40%. An interesting feature of the results is that subjects gave incorrect answers because of details. It seemed that subjects were scanning the details of the drawings until they recognised them, and finally putting them together and making an identification, (see also Kennedy 1974). The goat was sometimes identified as a cow, because the goat's tail was drawn hanging down, whereas in fact a goat's tail is held up.

The process of feature identification is the method used in identification of animals in the wild. Frequently the observer is treated to only a partial sighting or a fleeting view of the whole animal and a quick identification is best made by checking out identifying features.
A second set of drawings reported by Shaw revealed more difficulties in identification and show the importance of context as well as detail. For example, a drawing of a mortar with a pestle standing by it was identified by only about 20%. The reason might be that, while the mortar was realistically drawn, the pestle was too short and was standing up and apparently leaning against thin air (see Figure 1. From Shaw, 1969, p. 10)
Perhaps even more remarkable is the interpretation of a drawing of a cupboard as either a church or a schoolroom. The panels on the cupboard were the striking feature, and resembled rows of benches; in addition, correct identification of the cupboard involved the use of a linear perspective cue. The most fascinating misinterpretation was of the picture of a hoe, which some saw as a man walking along a road: several reasons may be found for this, one being that the hoe handle was drawn with straight lines, which is incorrect, for hoe handles are usually quite uneven; then the blade is drawn at right angles to the handle, which is also not normally the case. The blade of the hoe resembled a man's shirt. We must also, therefore, blame the artist for not producing faithful representations.

Holmes (1966) studied line drawings in a more comparative way. He found that too little detail detracted from correct interpretation, but addition of too much detail was also a barrier to identification. The balance is a fine one, and is not only disturbed by incorrect drawing on the part of the artist (who is, after all, for the most part accustomed to viewers who are able to give him great license) but also to the culturally biased preconceptions of the viewers. Fuglesang (1978) gives us a nice example (p. 85) of a photograph intended for use in a nutrition campaign. The photograph was in the Westernised advertising style of a smiling face, healthy and fresh in a rain shower.
But the healthy image was not carried to Lusaka illiterates who saw, not rain drops, but a skin disease on the boy’s face, and other deformities in the unusual light and shadow on his face!

Whether or not pictures can be recognised without training has important implications both practically and theoretically. One method of assessing this is that used by Hochberg and Brooks and reported above. Another method is to locate people who have never been exposed to pictures because of their geographical and cultural situation. Deregowski (1968) and Jahoda et al. (1977) used this second method in an attempt to replicate Hochberg and Brooks’ findings. Deregowski tested some Bisa schoolchildren and adult males who inhabit an inaccessible area of Zambia. Subjects were shown a three-dimensional array of 18 Britain’s Zoo animals, 6 of which were familiar to Bisa, and photographs of the same animals. They were then asked to look at the photograph and point to the model in the array. All subjects experienced more difficulty with unfamiliar than familiar animals; adults were worse than children on unfamiliar, but better on familiar material.

Jahoda et al. (1977) showed colour photographs of single objects against a neutral background to young children in Ghana and Rhodesia. The children (aged about 3 years) were from remote rural areas in Ghana and a rural area about 25 miles from Salisbury, Rhodesia. There was minimal use of pictures in these areas, although the
presence of a school in one of the Ghanaian villages led the authors to analyse responses from children in that village separately. The subjects were first asked to identify small common objects by handing the appropriate one to the experimenter when asked. They were then asked to identify photographs of the same objects in the same way. A set of photographs of large objects in natural settings was also included in the test. Mean percentages of correct picture responses ranged between 83% and 94%, which is 2-3 times the chance expectation level. There was no significant difference in correct responses to pictures of objects that had been handled as against those not handled (except in one instance, a picture of a stone, which was therefore excluded from analysis). There was also no significant difference in results between the rural children and children (aged about two and a half years) from relatively high socio-economic status families who were attending a nursery school.

This study lends credence to the Hochberg and Brooks view that visual experience of objects in the real world is sufficient to lay the foundation of an ability for picture recognition. The results fit in with the findings of Deregowski, already reported, and those of Kennedy and Ross (1975) to be dealt with later.

An important point here concerning Jahoda et al's materials is that they were coloured photographs with a neutral background, which maximised the chances of recognition. Fuglesang (1973) showed the importance of using
a neutral background in photographs. He made series of four pictures depicting the same subject matter in (1) a line drawing, (2) a silhouette, (3) a black and white photograph with normal background, and (4) a 'block-out' of the subject, that is, a photograph with the background eliminated. The study was undertaken in Zambia, and the pictures were all of local people and objects, for example a woman cooking, a man drinking, and a house. The pictures were presented vertically to the subject in series of four, held in a half circle by two experimenters, so that the distance to the eye should be equal. The order of the pictures from left to right was altered at random for each series of four. After having been shown the series, the subject was asked 'These four pictures show you the same thing, tell the same story. Can you tell us what you see?' When this was done satisfactorily, the subject was asked, 'Will you point out for us in which picture you saw this first?' During the interview, eye and head movements were followed closely and with few exceptions they indicated the same picture as was finally pointed out by the subject. 63 subjects were tested, and the overwhelming majority pointed out the 'block-out'. Photographs were pointed out next most frequently, with line drawings having the lowest number of point-outs and silhouettes having marginally more than line drawings. No statistical tests were performed on the data so they will be given in full:
The author does not say why 38 responses are missing, but presumably there were some subjects who were unable to state a preference. As can be seen from the results, statistical tests were hardly called for.

Work by Kennedy and Ross among the Songe of Papua suggests the influence of school education on picture perception, as well as providing further evidence that outline picture perception does not have to be learned. The authors found that subjects under 40 years of age had no difficulty in identifying outline drawings of common animals, objects and human forms. Respondents over 40 years were better able to identify drawings of the whole of a familiar object than just the part: drawings of part of a human figure, such as an arm, proved difficult, as did the
drawing of a canoe, an unfamiliar object to Songe. These subjects also failed to identify drawings depicting kinetic scenes of a river and a fire. A rather puzzling result is the number of young subjects (10-20 years) who correctly identified the deer, an animal totally unknown to the Songe. One possibility is that these subjects had come across drawings of a deer in books, perhaps at school; older subjects were almost without exception unable to identify the deer, and the authors state that these people had no formal education. Possibly one role played by education in facilitating picture perception is that of exposing people to a wider range of objects which can then be recognised in pictures. The general finding that Songe, who have essentially no indigenous art, are able to recognise outline drawings is in accordance with Hochberg and Brooks' and Deregowski et al's findings.

Some results from a study by Forge (1970) do not fit in so neatly. He found that Sepik (New Guinea) subjects were poor in picture perception. Forge used colour photographs, which would be expected to facilitate identification, but the subjects tended to concentrate on colour relationships and had difficulty with identification. However, when Forge added thick outlines to the figures in the photographs, and arranged for them to be photographed against a white background, subjects found them more comprehensible. This lends credence to the suggestion of Segall et al (1966) that outline drawings would present fewer difficulties than
photographs to naive observers because of their clear contour depiction. Kennedy and Ross (1975) mention that in informal testing, many of the Songe aged 40 and over who understood outline drawings had trouble recognising photographs, unlike the two younger groups who seemed to encounter no difficulty. This is also in accordance with Segall et al.’s view, and suggests that contour is more important than texture for the recognition of single depicted objects. In the light of Fuglesang’s findings with the block-outs, it is most likely that the addition of the contour line aided the subject in discriminating the object from the background. The cross-cultural data thus appears to support the view that recognition of objects in outline drawings does not have to be learned, but that learning is involved in pictures containing much detail, or symbolism. Hutton and Ellison (undated) found that, while after 6 years schooling New Guineans can correctly interpret, at a concrete level, simple line drawings, stylised artistic conventions considerably reduce understanding. As will be seen in the next section, pictorial materials such as posters which have been designed to convey a message are often misinterpreted.

Identification and interpretation of more complex outline drawings

There is ample evidence that more complex pictures,
often drawn by the artist to convey a message, are interpreted in a way different to that intended. For instance, an artist setting out to convey a message might construct a poster or picture which highlights what he considers to be the important aspects of his message. An observer might fail to extract the message for perceptual or conceptual reasons, and he might fail to give evidence of understanding for expressive reasons. In the case of a picture which portrays a three-dimensional scene, the failure could be due to the observer not making the assumption that depth is portrayed on the flat picture surface. A lack of knowledge of artistic conventions might result in a failure to extract the message for conceptual reasons, and a linguistic or social factor could result in a real or apparent lack of understanding. Hudson (1960 p.183) reports that protocols from a picture perception test administered in 1957 to a group of Bantu factory workers contained interesting misinterpretations.

"One of the scenes was drawn to represent the home-coming of the migrant industrial worker. The scene contained the figures of an elderly couple seated on the ground. In the background was a thatched circular hut, with the figure of the worker clad in overalls, arms akimbo, superimposed upon it. Seven protocols referred to a winged being, a devil or an angel. By accident, the artist in superimposing the foreground figure on the hut, had
placed the ragged thatched roof of the hut in such a manner that an observer, who did not perceive depth in the picture, would see the thatch as feathers or wings sprouting from the worker's back just above his shoulders. His posture, with arms akimbo, aided this interpretation."

"The second picture was intended to represent a demagogue haranguing a group of workers. As a dominating figure, he was placed above the workers, and in the background to lend atmosphere to the picture, the artist included a long factory-like building with three tall smoking chimneys. Again, by accident, the demagogue's outstretched hands were positioned just above the tops of the two chimneys. Thirteen protocols refered to the madman who had climbed up to the top of the houses and was warming his hands at the smoke. This interpretation was correct, given a two-dimensional perception of the picture."

Similarly, Wendy Winter (1963) in a study of workers' interpretation of industrial safety posters, found that the posters were frequently misunderstood. In addition to 'cultural' errors by the artist (eg. drawing a man who is receiving money with his arms apart instead of with hands cupped together) there were misinterpretations of 'kinetic'
messages. Thus a poster depicting a man throwing a hammer which hit a workmate on the head was interpreted as a poster with the message that workers must look at what they are doing, rather than a message that they should not throw tools.

Another example, cited by Deregowski (1976) was used in a Unesco study and depicts a family scene. The family group was inside a house, with a female figure seated on the floor beneath a window. The East African viewers said that the window was a four-gallon tin of water carried on the woman's head. Hudson (1967) also reported difficulties with artistic conventions eg. impact marks and shock waves, which were interpreted respectively as the sun and wrinkles in a man's shirt. In general, lines which do not depict contours frequently pose problems for naive observers. Thus a significant proportion of Hudson's subjects misidentified the 'road' and the 'horizon' in his Pictorial Depth Perception Test (which will be referred to more extensively later). Hudson also reports on the misinterpretation of foreshortening by many viewers who consider it to depict deformation.

In summary, it seems that people without prior pictorial experience are able to recognise familiar objects in drawings and photographs, as long as the pictures are clear and uncluttered. This implies that a picture does contain some information which can be treated as equivalent to that received from objects in the environment. It
appears, as Deregowski suggested, that viewers pay attention to features of the drawing, and test hypotheses by referring back to other features. The fact that the block-out was more frequently pointed out than the photograph in Fuglesang's study suggests that clear separation of the figure from the background also aids identification.

The position is very different once lines other than contour lines are involved. Lines suggesting movement and impact, perspective and colour boundaries are not automatically understood. Learning is required, and while most Western children assimilate this knowledge at an early age, it cannot be assumed in people not brought up in a pictorially educated environment.
CHAPTER TWO

Perception of depth in pictures

In this Chapter, the information used in the interpretation of depth relations in the real world and in a pictured scene will first be summarised. The accuracy of Western adults in the estimation of size and distance in photographs will then be considered and will be followed by a presentation of research on the development of pictorial depth perception in Western children. Finally, the cross-cultural work on pictorial depth perception will be reviewed.

Information for flatness and depth in a picture.

In making judgements of distance in a three-dimensional scene, the observer may use several sources of information. Some of this information can be picked up only when both eyes are used, and is referred to as binocular; some can be picked up by one eye alone and is referred to as monocular. One of the binocular cues is the convergence of the two eyes on the object which is being examined, in order that the images are brought to the foveas. The angle of convergence is greater when the object is nearer than when the object is farther away, and the distance is signalled to the brain by this angle. Convergence is thus a powerful cue to depth,
but it can only give information about the distance of one object at a time, and that is the object whose images are fused by the convergence angle. A second binocular cue to depth is retinal disparity, which arises from the fact that each eye receives a slightly different image of any one object. The two disparate images are integrated by the brain and an impression of depth results. Retinal disparity is insignificant when an object is distant (over 50 metres).

A greater number of optical sources of information for distance and size are also available when viewing is limited to only one eye. Motion parallax provides evidence for the relative distances of objects, through the differential rate of translation across the retina of the images of objects moving across an observer's line of sight, and may be produced by the movement of the observer or of an object. Other monocular cues are available to the stationary eye, and they are:

i. texture gradient, the increasing density of texture elements with distance;

ii. linear perspective, the convergence of parallel lines with distance;

iii. interposition, the covering of a portion of a more distant object by a nearer object;

iv. aerial perspective, the relatively lesser clarity of more distant objects;

v. position in the field (elevation), with more distant objects on a level ground plane appearing higher in the visual field than nearer objects;
vi. relative size of objects, the more distant of two equal sized objects subtending a smaller visual angle;

vii. shadow, with the shadow cast by the nearer of two equal-sized objects subtending the larger visual angle.

When viewing a picture, binocular cues and motion parallax provide information for the equal distance of the forms on the picture surface. Some ancillary factors emphasise that the viewer is looking at a picture, for example framing, which segregates and directs attention to the picture as a thing. The medium of representation may also draw attention to the surface if the surface itself has been altered by scratching or by the deposition of materials. It is the static monocular cues that provide information for depth in a picture.

In order to portray depth in a picture, the artist must incorporate cues for depth, and in order to construct perspective relations appropriate for a particular viewing position or station point, he must use geometrical projections to that point. It is as though the artist stood with a sheet of glass held perpendicular to his line of sight and painted what he saw onto the sheet of glass. A scene drawn in perspective defines the shape, size and disposition of the objects drawn in the picture for one eye only in a given position, or station point. If an observer looks at the picture monocularly from the correct station point and keeps his head still, the perspective impression is greatest. It should be noted, however, that although architectural drawings may be drawn in strict perspective,
an artist may modify perspective in order to correct too sharp a convergence or foreshortening, and this modification relies on the artist's judgement of what looks natural.

With binocular vision, as Helmholtz (1896 p. 609-10) pointed out, the flatness of the picture is more apparent. At the beginning of the twentieth century, when interest in stereoscopy was high, it was well-known that a depth effect could be obtained almost as well by viewing a single picture through a lens as by the use of disparate pictures in the binocular stereoscope. As Schlosberg (1941) pointed out, the effect was achieved by eliminating cues to flatness (binocular cues and motion parallax). Flatness cues could also be reduced by other methods such as viewing with one eye through a tube or looking at a picture in a mirror, and a combination of mirror and lens was found to be especially effective. The depth effect can also be enhanced during binocular viewing by viewing from a distance, but this often yields incorrect linear perspective with ordinary paintings and most photographs. In addition, if two identical pictures are viewed binocularly with a viewing lens in front of each eye, so that the effects of identity of the two retinal images are overcome, again the depth effect is enhanced. Schlosberg concluded that the "...absence of binocular differences is not an all-powerful cue to flatness".

Interestingly, a painting which has been credited as the first example of linear perspective, was probably made by the use of a viewing method like that above. Lynes (1980)
shows how Brunelleschi probably constructed perspective in his painting of the Baptistery of San Giovanni by a clever use of mirrors, and suggests that it was for this reason that Brunelleschi chose to paint a symmetrical building (and one that he would not normally have chosen because it was designed by a great rival). Observers looked at the painting through a small hole, 'the size of a lentil bean' i.e. monocularly and without head movement, and held a mirror so that the painting was reflected in it. The impression of three-dimensionality was remarkable.

More recently, both Gibson (1954) and Hochberg (1962) have shown that viewers may be unable to detect the difference between a real and a pictured scene under restricted viewing conditions. Gibson allowed subjects a peephole view of a high quality photomural of an empty and dimly lit corridor, and a similar view of the real corridor. Both the photomural and the corridor subtended the same angle to the eye and the structure of the optic array projected by the corridor was replicated in the optic array from the photograph. However, the photograph was in black and white only. Subjects had to judge which was the view of the real corridor, and which the picture. About a third of the subjects judged the photograph to be the real corridor.

Hochberg (1962) framed a model house which was sprayed with paint from an angle so as to make it appear to be illuminated at variance with the illumination of the room in which it was viewed. The model was covered with cellophane in order to eliminate surface-cue differences between it and
A picture of the model placed next to it. Hochberg found that with unrestricted binocular viewing from 10 feet, observers did not spontaneously notice a difference between the model and the picture; with monocular viewing it became extremely difficult to detect which was picture and which object. Hochberg does not actually give any information concerning numbers of subjects who viewed the display, however.

A feature of great importance to the artist in establishing the scale of his picture is the position of the horizon line (or implied horizon line) in relation to the objects in the picture. The position of the artist's eye when painting the picture (and equally, of the camera lens when taking a photograph) in relation to the horizon line forms a baseline on which the scale of the picture is constructed. The horizon ratio relations became apparent with the development of perspective theory. White (1957 p.23) defines the relationship: "the height of (any object's) various parts will then be governed by multiples, or fractions, of the vertical distance between the horizon line and the part of the foreshortened plane on which they stand." Sedgwick (1973) gives a simplified version of this relationship when he shows that "the ratio of the height of the object to the height of the point of observation is approximately equal to the ratio of the optic array angle subtended vertically by the object to the optic array angle subtended vertically by the portion of the object that is below the horizon." The true ratio is the ratio of the
tangent of the angles, but as the tan function is nearly linear for small angles, the angles themselves can be substituted to give an approximation which is easy to use.

In the following sections, some work showing the accuracy of Western adults on the estimation of size and distance in photographs will be presented. This will be followed by a consideration of the perception of depth in pictures by Western children, and then by a review of cross-cultural studies of pictorial depth perception.

Perception of depth in pictures by Western adults

In a series of experiments with photographs, Smith and his colleagues have shown that Western adults are remarkably accurate in estimating the size and distance of objects (Smith 1958a, Smith and Smith 1961, Smith, Smith and Hubbard 1958). Smith (1958a) asked subjects to estimate distance in Gibson's black-and-white photomural of a 109.7 metre corridor. Subjects were able both to estimate distances from the viewpoint to specific parts of the pictured scene, and to estimate distances between places in the scene. Smith and Smith (1961) demonstrated that subjects can think they are looking at a real scene when in fact they are being shown a picture, and can then go ahead and estimate distance in it. Subjects looked through a peephole at a photograph of a room behind a screen and then had to throw a ball at a target in the room. Accuracy of throws to the photograph was good, ranging from 97% (an underthrow) to 106% (an
overthrow), in comparison with accuracy of throws to the real room which ranged from 96% to 100%. None of the subjects reported that he realized he was looking at a photograph.

Smith, Smith and Hubbard (1958) tested subjects' ability to judge distance in four displays. The first was the photograph of the 109.7m corridor used in previous experiments, and the other three were line drawings of the corridor, varying in detail and shading. In the first line drawing all the perspective lines of the corridor were drawn, while in the second only a few were drawn and some detail was included; in the third and fourth drawings only the primary perspective lines were drawn, and the third drawing differed from the fourth in being shaded. No significant differences were found in the subjects' accuracy of distance estimation in response to the photograph and the line drawings.

Gibson and Smith (1952) also demonstrated that subjects' size estimation in photographs was highly accurate, and that size estimations did not vary as a function of distance estimations. They used reproductions of Gibson's stake photographs which showed 15 stakes, the standard stimulus objects, in an arc 12.8 metres from the camera. The shortest, 68.6cm high, was to the left, and each adjacent stake was 10.2cm higher, the tallest being 210.8cm high. A 2.44m gap in the centre of the arc permitted S to view the distant stake. Sixteen photographs were made, one of each of 4 stakes ('variables'), 160, 170,
180, and 190.5cm high at each of four distances, 25.6, 102.4, 204.8 and 409.65 metres from the camera. The distance setting of the photographs, at which they reflected patterns of light approximating those that entered the lens of the camera, was 50.8cm. Gibson and Smith found that judgements of the size of the far stake were slight underestimations of the actual mean height of the variable stakes, which was 175.3cm, (judged size at 25.6m was 174.1cm) and did not vary much with distance. Judgements of distance were accurate at 25.6m (judged distance was 26.2m) but became increasing overestimates with increased distance of the far stake (judged distance of the stake at 409.7m was 490.5m). Smith (1958b) found that subjects' distance estimations were dependent on the magnification of the photograph. In addition, one of the photographs was modified by deleting all detail except for the standard and variable stakes, thus eliminating all texture-gradient information. This made no significant difference to subjects' estimations of height and distance.

An important point in all of Smith's experiments is that subjects received instruction prior to making their estimations to the effect that they would be shown a picture or photograph of a hallway or a field stretching away in the distance. Western adults are able to make estimations of size and distance according to instructions (see the effect of instructions on the operation of constancy scaling mechanisms reported in Chapter Three), and it would be expected that the instructions in Smith's experiments would
enhance subjects' ability to make accurate estimations. The lack of any effect of texture gradient might also be due to the overriding effect of instructions.

The development of pictorial depth perception in Western children

Studies of the development of pictorial depth perception in Western children have tended to focus on the relative influence of the different cues to depth and have used a variety of testing techniques and materials. The cue of linear perspective has received most attention in these studies, but interposition, texture, height in the picture plane and shading have also been investigated, as well as the information for the flatness of the picture plane.

Wohlwill (1962) used a method somewhat similar to those used in the estimation of size constancy (see Chapter Three) to assess the influence of texture density and perspective on size and distance judgements. He showed subjects four perspective drawings, in which the perspective was provided by black rectangles on a tapered field. Randomness of the marks and texture density were manipulated over the four drawings to produce two random and two nonrandom fields, and a high texture density and low texture density version of each. The drawings were displayed on a vertical panel behind a sheet of Plexiglass. Subjects had to i) make a distance judgement by trying to locate the vertical midpoint between two screws which were located on
the Plexiglass cover on an imaginary line passing through
the vanishing point of the perspective drawings, one screw
near the top edge and the other near the bottom, while the
drawings formed the background. The experimenter moved a
little plasticene ball attached to a loop of fine nylon
thread up or down until the subject told him to stop because
he thought the ball was midway between the two screws. ii)
Subjects had to make a size judgement, altering the size of
either a rectangle located at the top of the drawing or the
one located at the bottom, until they appeared to be the
same size. Instructions to Ss were such as to encourage an
objective judgement (they were to match the actual physical
sizes of the rectangles). Subjects were children from
Grades 1, 4 and 8 and college-age adults (24 Ss in each
group); mean ages of the groups were 7:1, 9:10, 14:0 and
20:0 years. For the distance judgements results were as
expected: the effect of perspective was greater for the high
density than for the low density fields and greater for
nonrandom than random fields; the overall effect of
perspective, however, appeared to decrease with age, the
three groups of children having significantly different
results from the adults but not from each other. There was
a marked anticipation effect which was greatest in the two
youngest groups. The results for size were much less
consistent and less in agreement with expectations than the
results for distance judgements, for, while the non-random
patterns elicited a greater size illusion than the random
patterns, a control field with no perspective information
elicited an illusion effect intermediate between the two random and the two non-random patterns; also, the illusion effect of the two high density panels were marginally (but not significantly) lower than the means for the low density panels.

Wilcox and Teghtsoonian (1971) attempted to overcome some of the problems that arise from verbal questionning in this kind of testing by developing an operant conditioning procedure. Subjects were trained on a variable ratio schedule to respond to the larger of two geometrical figures (circles, squares or triangles). They were then tested with a series of slides, some of which depicted two figures of equal area placed so that one appeared to be at a greater depth; in others, there was an actual difference in area between the two forms. Backgrounds included texture and perspective effects and the cue of interposition was used as well. All subjects had a high correct response rate to RAD (real area difference) slides, but 3-year old and 9-year old groups were less often correct than adults on the IAD (illusory area difference) slides. There were no significant differences according to depth cues.

A study by Yonas and Hagen (1973) was based on the findings of Wilcox and Teghtsoonian, and tested the hypothesis that sensitivity to pictorial information is present in 3-year olds but is suppressed because young Ss attend to information for the picture plane, while older Ss ignore it. Subjects viewed a display of two objects in an alley monocularly either through a slot, in which case
motion parallax was available because the head could be moved, or through a hole, in which case no motion parallax information was available. The displays were either of actual objects placed in the alley (3D) or photographs of the 3D displays (2D). The larger object was placed so that the visual angle it subtended was approximately 70%, 80% or 100% that of the smaller object. Subjects were asked to indicate which of the two objects was the larger. With the visual angle of the larger and smaller objects the same, all subjects performed better than chance. But when the visual angle subtended by the larger object was approximately 70%, the younger subjects performed below chance under all conditions except for the 3D with parallax. For 3- and 7-year olds, the addition of motion parallax information while viewing the 3D display significantly increased accuracy. Thus motion parallax (which provides extra information for the picture plane) diminished children's sensitivity to differential distances and sizes of the objects in the pictorial displays. The effect of conflicting information for pictorial depth was greater in children than in adults.

Yonas and Hagen suggest that the difference between their results and those of Wilcox and Tegotsoonian is due to the comparison objects used. Yonas and Hagen used objects which were 2 inches thick, and cast shadows on the alley floor, whereas Wilcox and Teghtsoonian used squares which were superimposed on the pictures and did not cast shadows or obviously rest on a surface. There are also procedural differences that might have contributed to the differences
in results: Wilcox and Teghtsoonian's subjects viewed the photographic slides binocularly, with unrestricted head movement, whereas Yonas and Hagen's subjects viewed monocularly, some with and some without head movement. Binocular viewing would provide additional information for the flat picture surface. Also, Wilcox and Teghtsoonian's 3-year olds received their testing session a day after their training session, and the test scores might reflect some forgetting. Both studies showed that the older children and adults were responsive to pictorial information for depth. The findings of Yonas and Hagen support the thesis that a picture presents conflicting information for a three-dimensional representation and for the two-dimensional picture plane, and that children gradually learn to attend to the information for the three-dimensional representation. Also, they have developed a technique whereby the development of the ability to attend to this information can be monitored.

Benson and Yonas (1973) investigated development of sensitivity to the cue of shading in photographs and to the cue of linear perspective in line drawings. They found that, when the test pictures, depicting 'bumps' and 'holes' were oriented vertically, both 3-year old and 7-year old subjects were sensitive to shading information and there was no significant improvement with age. When the pictures were oriented horizontally, the 3-year olds' error rate was much higher. The authors suggest that adults 'assume' the source of illumination to be at the top of the picture and that
perhaps the ability to employ a spatial reference system other than the gravitational one in viewing a picture develops with age. The explanation might also lie in the experience of adults who assume that pictures are taken with the camera held vertically, so that the picture does represent a vertical plane even though it may be placed horizontally for viewing.

Yonas, Goldsmith and Hallstrom (1978) found that young children (aged 3 years) displayed some sensitivity to the information provided by shadows for the size and shape of the objects in a picture. The location of the shadow in relation to the object also provides information for the perceived depth of the object and its height off the ground plane. Three-year olds were sensitive to the location of cast shadows, but there was evidence of improvement with age in judging the distance and size of the object. Hagen (1976) also found an increase with age in accuracy of judgements of the location of a light source necessary to obtain photographs of objects with shadows in the positions shown. Kindergarten children were highly inaccurate but by 3rd grade the error rate had been halved.

Benson and Yonas (1973) also studied the influence of linear perspective information in Gibson's (1950 p. 182) drawing of three cylinders in a hallway. Half of the 32 3-year old nursery school subjects were shown the drawing with the linear perspective information and the other half were shown the same picture with the linear perspective information removed. They were asked if they saw the three
blocks in the picture, and when they said 'yes', they were asked "Which is the fat one?" In order to rule out the possibility that Ss were choosing the one highest on the picture plane, they were also shown the picture rotated through 180 degrees and asked the same question. The order of trials was counterbalanced.

Results showed that, with linear perspective information present, 14 of the 16 children chose the pictorially 'farthest' cylinder, and that rotating the picture made no significant difference. When perspective information was removed, the three cylinders were chosen with almost equal frequency. Thus 3 year olds are sensitive to perspective information in this picture, but are not sensitive to the position of an object on the picture plane. This was also true for a sample of ten adults.

The authors suggest the reason that their results differ from those of Wilcox and Teghtsoonian lies once again in the picture itself. "According to Gibson (1950) the amount of surface occluded by an object as it rests on a surface provides information for perception of size. In this experiment, the cylinders had a strong three-dimensional appearance and clearly appeared to be either resting on the floor of the hallway or attached to its ceiling." What is of importance, and not referred to by Benson and Yonas, is that the object occludes several linear perspective lines.

These findings are consistent with those of Newman (1969) who investigated sensitivity to the perspective
illusion in children aged 6, 10 and 14 years. He used an adaptation of Gibson's (1950) hallway drawing, replacing the three cylinders with two black posts, the foreground post being of variable length. Subjects were asked to change the length of the variable until it appeared equal in physical length to the standard. (In two trials the experimenter adjusted the variable, but results were the same regardless of whether E or the subject made the adjustment.) After testing, all subjects were asked if the picture represented anything to them, and they were classified as being 2-dimensional or 3-dimensional interpreters of the picture on the basis of their response to this question. Newman found that 6-year olds' size judgements were strongly affected by perspective, and the 6-year old children who gave a three-dimensional interpretation of the picture were more strongly affected by the illusion than the others. However, the judgements of the 6-year olds who gave a 2-dimensional interpretation of the picture were also influenced by the illusion, and Newman deduced that young children can be influenced by perspective in a picture before they can give a definite interpretation of the picture in depth. There was no significant increase in susceptibility to the illusion with age. It would thus appear that children can be influenced by perspective without explicit realisation. The relative lack of sensitivity to linear perspective in other studies may well be due to the amount of information conveying linear perspective in the pictures.
Jahoda and McGurk (1974b) used three series of colour pictures depicting two female figures walking diagonally across a green field with one figure in the rearground and the other in the foreground. They varied linear perspective information by introducing in one series a path along which the figures walked, and in another series a fence running alongside the path. The sizes of the figures were manipulated so that in each series the pictures depicted either two 'ladies' or two 'girls' or one 'lady' and one 'girl'. Scottish children aged 4-10 years were asked to select model 'ladies' or 'girls' according to their perception of the picture and to position them on a response board in such a way as to indicate the positions shown in the picture. Size estimation as indicated by selection of the correct models increased with the addition of linear perspective provided by the path and the fence. Spatial perception, as indicated by the positions in which the dolls were placed, was reduced by the addition of linear perspective information. The authors interpret their findings in terms of the influence of the frame of reference provided by the path and the fence. They propose a developmental sequence analagous to the stages outlined by Piaget and Inhelder (1956) to account for the child's construction of the projective line. During the first stage of development, subjects use the contour of the picture as their frame of reference, and thus align their models with the bottom horizontal boundary. During the second stage, subjects begin to employ the internal structure of the
picture as the frame of reference, providing that there are few other frames in competition. Finally, subjects become free of all frames other than that provided by the internal structure of the picture.

McGurk and Jahoda (1974), using a black-and-white version of the test described above, tested children aged 4-10 years on pictures having only elevation as a cue to depth. They had three variations of posture of the two figures, one in which the direction of walk was horizontal, a second with diagonal walk, and a third with the figures in a stand-easy pose. There was no effect of posture, and they found that elevation alone provided a weak but effective cue to depth. They also suggest that 4 year olds' errors were response based, being a reflection of a difficulty in the selection and positioning of the models rather than an indication of a perceptual difficulty and therefore perceptually based.

Hagen (1976) did not find elevation to be consistently utilised as a depth cue by children aged 3-7 years, whereas all age groups she tested successfully perceived the depth relation information provided by pictorial overlapping. Dunn, Gray and Thompson (1965) found that adults utilise height in the picture plane as a cue to depth. It remains to be established just when this ability develops. Cox (1978) suggests that children may be more competent than they appear in some experiments because verbal instructions are not in themselves sufficient to enable the child to grasp the nature of the task, which then becomes a test of verbal
comprehension. On being shown pictures of two balls, one of which was above the other, the majority of 5-, 6- and 7-year old children said that the lower object was nearer.

Olson (1975) attempted to compare sensitivity to different kinds of information for depth in young children of 3 and 5 years using a restricted (monocular, no head movement) and an unrestricted viewing condition. His photographs were of coloured model houses on a table against a vertical blue backboard; linear perspective information was provided by a grid of squares drawn in black ink on white poster board. The other cues used were height in the picture plane and interposition. In all pictures there were two houses (one red and one green) and Ss were asked to specify which one was closest or farthest. Subjects underwent a qualifying session in which they were shown pairs of model houses in a three-dimensional array and were asked to specify which was closest or farthest; only children who reached a criterion of six consecutive correct responses in the first twelve trials performed the test. Results indicated sensitivity to depth information but a lack of significant differences between cues which Olson suggested was probably a ceiling effect. There was also no significant difference for the viewing conditions, which suggests that the children had already learned to ignore information for the flatness of the pictures. The difference between this finding and that of Yonas and Hagen (above) might have resulted from one of several factors. Perhaps most important, Olson's subjects were asked to make
relative distance judgements whereas Yonas and Hagen's subjects were asked to make relative size judgements. In addition, Olson's subjects received a training session with the test objects in a three-dimensional array, which might have resulted in a bias towards a three-dimensional interpretation of the test picture and would also have familiarised the subjects with the relative sizes of the houses. The fact that the photographs were in colour would have facilitated identification of the houses, and the blue background would be readily associated with the sky and hence the scene depicted would be recognised as three-dimensional.

In a later study, Olson and Boswell (1976) tested 15 two-year old children on the task reported above. Only 8 children completed the task; 4 failed to meet the criterion and 3 did not finish the test. Of the remainder, the results indicated that the children were able to make accurate depth judgements from pictures with either the cue of interposition or of relative height in the picture plane. Relative size on the picture plane had no significant effect on performance.

In general, the above studies do point to a sensitivity to pictorial depth information in young children, although the degree of sensitivity is dependent on the pictorial content, the experience of the children, and the testing procedures used. It has been shown that linear perspective can be utilised as a cue to depth by children as young as three years of age, and the efficacy of the cue appears to
be greatest when there are more than two lines indicating perspective. Both the studies which showed an influence of linear perspective (Newman 1969, Benson and Yonas 1973), used Gibson's (1950) drawing of a hallway in which the optical information was faithful to the real scene, and in which there were many lines indicating the boundaries of the hallway which converged in the distance. The objects displayed in the hallway ocluded several perspective lines and this would add to the strength of the cue. Wohlwill's (1960) drawings gave several perspective lines, and it was shown that perspective influenced subjects' distance judgements, but not size judgements. In this case, however, the rectangle lower in the picture plane ocluded several perspective lines while the rectangle higher in the picture plane did not: this might have contributed to the lack of any influence of linear perspective on size judgements.

Shading and shadows can also be used by young children as cues to depth, but children are more sensitive than adults to the orientation of the picture, and judgements of the location of the light source necessary in order to obtain particular photographs improve from kindergarten through third grade.

Cross-cultural assessment of pictorial depth perception

The major portion of the work reported in this section was carried out in Africa, and much of it relied to some extent on the Hudson Pictorial Depth Perception Test
Hudson's work (1960, 1962a & b, 1967) using this test will therefore be described first.

The Hudson test material consisted of eleven outline drawings and one photograph; five of the outline drawings represented vertical space, and the remainder of the drawings and the photograph represented horizontal space. As very little reference is made in the literature to the drawings of vertical space, they will not be discussed further. Pictures 1 to 6 (horizontal space) were designed to test responses to pictorial cues of size, overlap and linear perspective. Each picture showed an elephant positioned centrally between a man and an antelope. The man and the antelope were on approximately the same horizontal level, whereas the elephant was more elevated; the elephant was drawn relatively smaller than the antelope. In all pictures also, the hunter's assegai was aligned on both the elephant and antelope. Hudson (1960) explicitly mentions that the cue of object size was present, but does not appear to recognise that the cue of height in the picture plane was also present in all six pictures. Pictures 2 and 3 had additional cues of overlap; while Pictures 4, 5 and 6 had straight perspective lines representing a road with its vanishing point on the horizon. All the pictures were outline drawings with a minimum of detail. The photograph, Picture 12, was of a modelled hunting scene and was similar to picture 1 except for the fact that the elephant stood on the horizon line and the hunter and antelope intersected it.

Subjects were asked the following questions about each
picture:

1. What do you see?

2. What is the man doing?

3. Which is nearer the man, elephant or antelope?

"Responses to question 3 were taken as indicative of the type of dimensional pictorial perception possessed by a candidate." If a subject reported the antelope to be nearer the man, his responses were classified as three-dimensional (3D). Hudson also considered the response to question 2 to indicate three-dimensional perception if the subject said the hunter was aiming his spear at the antelope: however he does not appear to have used responses to question 2 in his analysis.

There were eleven samples of subjects (Hudson 1960), six of them being school attenders; five of these samples were schoolchildren and one was of adult teachers. Five samples consisted of mineworkers: two of illiterate black labourers, one of black labourers with primary education only, one of white labourers having no education or primary education only, and one sample of black clerks with high school education. There were two samples of black school children: one Standard 6, the other Standards 8 and 10; there were also three samples of white schoolchildren in the first years of Primary school (Grades and Standard 1), throughout Primary school (Grade 1 to Standard 6) and at the end of Primary school (Standards 5 and 6). Hudson gives only age ranges for the samples - the white schoolchildren were under fourteen years and the black schoolchildren were
14-20 years. Hudson's selection of samples was not designed to facilitate cross-cultural comparison.

Results showed first that, in response to question 1, (What do you see?) subjects were able to identify the man, animals and bird, although the antelope was sometimes identified as a goat and the elephant as another animal, such as a hippo. However, the hill, horizon and road were frequently misidentified as objects, the horizon being called a stick or ruler and the road a hill or tree. The mineworkers, black and white, most frequently misidentified all these features, but a substantial proportion of schoolgoers misidentified the 'road'.

Responses to the photograph were interesting. Unfortunately Hudson only tested one of the groups of mineworkers with the photograph and none of them gave the 3D response. However, the scores for all the other groups were greatly elevated over their scores for the outline drawings containing only the size cue. Hudson makes very little comment on this result, but it indicates that subjects' difficulty with the outline drawings has something to do with the drawings themselves.

Hudson does consider the semantic problem posed by the question 'Which is nearer the man, elephant or antelope?' Subjects could give either a topological or a projective response to this question. Hudson contends that the immediate responses of subjects to this question is evidence that they saw no conflict in the question and were therefore not mentally measuring the distance from one part of the
drawing to another. Immediacy of response is no indication of the way subjects were responding in this case. The graduate teachers were, strangely, the ones who hesitated most and were obviously able to see two possible ways of responding - we are told that some of them took as long as one hour per picture to respond. Subjects in this group asked for guidance in their perceptual choice.

The white school-attending samples were differentially affected by the specific depth cues and for them, the presence of interposition increased the 3D responses, while perspective information reduced them. Hudson states (1960, p.193) that the black samples (both school attenders and unschooled) were less responsive to different depth cues, but he does not support this assertion statistically. This could have been a baseline effect in the case of two of the samples (illiterates and mine labourers with only primary schooling) because they gave virtually no 3D responses at all. Hudson does not mention the black mine clerks who had a higher percentage of 3D responses with the cue of interposition than with the other cues.

Hudson concludes that educational and home experience with pictorial materials is conducive to three-dimensional understanding of pictures. This view receives some support from a comparison of Western schoolchildren from areas of varying degrees of isolation (Jones 1974). Sons of Labrador fishermen, who were very isolated, were compared with boys from a less isolated fishing community in South Newfoundland, and with boys from the city of St. Johns whose
fathers were of the same socio-economic level as fishermen. The isolated Labrador boys gave significantly fewer 3-D responses to the Hudson pictures than the St. Johns boys; the boys from South Newfoundland were intermediate. Baikie (1971), using a different test, also found significantly better perception of pictorial depth by advantaged children over disadvantaged children in the U.S. In another study using the Hudson Test, Duncan, Gourlay and Hudson (1973) confirmed the finding of a significant difference between Bantu and Western subjects. They also found significant differences between urban and rural Zulu and Tsonga, with the responses of the urban group being more similar to the Western responses.

Mundy-Castle (1966) used four pictures from the Hudson test, one had only object size as the cue to depth, two had linear perspective and one had interposition. He found that only one out of 122 primary school children he tested in Ghana gave consistent 3D responses.

Kilbride and Robbins (1968) used the same four pictures as Mundy-Castle to test the use of the linear perspective cue with increased educational level. They did this by asking 523 Baganda subjects, whose ages ranged from 4 to 75 years, to identify the 'road'. They found that the more educated subjects were better able to identify the road. Kilbride, Robbins and Freeman (1968) also found that the cue of interposition was utilised by subjects at a lower educational level than the combined cues. Identification of the cue does not imply perception of pictorial depth but
misidentification (e.g. ladder, snake) would deprive the subject of depth information. The authors do not say whether the subjects who misidentify the road were the ones who failed to pick up the cue of interposition.

Such black and white outline drawings are perhaps the most impoverished of the commonly used methods of representation. There is no texture gradient, no colour, no shadow to give an impression of solidity. In addition, the horizon line provides conflicting perspective information, especially in Hudson's pictures 1 and 2. Hagen and Jones (1978 p. 186) have shown Lloyd Held's projective extrapolation of the elephant in one of the Hudson pictures; the top of elephant's head is only as high as the hunter's armpit, and the authors ask whether we are to conclude that Hudson intended to portray a baby elephant, or that the artist did not do his sums. It must also be pointed out that the tree is rather short in relation to the spread of the foliage. All of these factors turn the interpretation of the Hudson drawings into a cognitive guessing game rather than a basic test of pictorial depth perception. Pictorially sophisticated viewers often verbalise these feelings when faced with the Hudson test.

Omari and MacGintie (1974) administered a revised version of the Hudson test using the same depth cues but with familiar characters in neutral poses. The subjects were Tanzanian children in grades 1, 3, 5 and 7 of Primary school. Revised version scores were higher than those for the Hudson test pictures and they increased with grade; the
scores for the original version were very low in all grades. They also found that urban children scored higher than children from a rural area. Not only are scores sensitive to the pictorial content, but also to the wording of the question. Omari and Cook (1972) found that the question "Which is 'farther' from the man....?" elicited significantly more 3D responses than "Which is 'nearer'.....?"

Hagen and Johnson (1977) carried out a similar kind of study in America, but in addition to comparing an American version of the test with the African version, they also varied the wording of the questions, comparing "Which is nearer the man(boy), the elephant (girl in blue shirt) or the antelope (girl in red shirt)?" with "Which is the hunter aiming at, elephant or antelope? (Whom is the boy throwing to, the girl in blue or the girl in red?)" This was done to test Hudson's assumption that the two questions solicit identical information. Subjects were first, third and fifth grade children from a Boston area elementary school, and adults from an Introductory Psychology course at Boston University. Results indicated no developmental change with grade with the American version of the pictures, but a gradual increase in three-dimensional responding with age to the African pictures, which failed to reach a ceiling even in college-age adults. The American set of pictures evoked more three-dimensional responding than the African set; and the two questions elicited differential responding to the African set, with the 'nearer' question evoking more 3D
responding than the 'aiming' (or 'throwing') question. The type of question was irrelevant with the American pictures. The question "Which is nearer, the elephant or antelope?" evoked more than two-and-a-half times the number of 3D responses evoked by the question "Who is the hunter aiming at, the elephant or the antelope?"

Waldron and Gallimore (1973) also developed a test based on Hudson's, by substituting human figures. Each scene portrayed a man and a woman in the foreground, and a mother and child in the rearground. They found that the European samples (7th grade children and Royal Australian Navy applicants) experienced less difficulty than indigenes of Papua New Guinea, Torres Straits Islanders (also RAN applicants) and Aboriginal children (7th grade).

Deregowski (1968) found that a significant proportion of Zambian schoolboys and domestic servants who were judged as 2D perceivers on the Hudson test were able to construct three-dimensional models of pictures of geometric objects. The domestic servants more often gave two-dimensional responses than the schoolboys. In a second experiment, Deregowski (1969) used the same construction task as a measure of pictorial depth perception. He hypothesised that subjects who were able to perceive pictorial depth would have greater difficulty retaining and reproducing a drawing of an impossible figure, the two-pronged trident. The results supported the hypothesis. Munroe and Munroe (1969) tested Logoli (East Africa) and American children with two of Hudson's pictures and five of their own, of different
construction. They found that a 'large proportion' of a sample of 5th and 6th grade children in the U.S. did not give fully three-dimensional responses. Four of their own pictures elicited much higher rates of 3-D responding than the Hudson pictures. They conclude that the problem lies in the pictures themselves.

The Hudson test, therefore, cannot be regarded as a test of whether an individual is able to perceive a picture as a three-dimensional representation. It appears, rather, to consist of a difficult set of pictures, which tap sophisticated pictorial skills and cognitive reasoning as well as a tolerance for artistic aberration. The questions considered by Hudson to be equivalent appear not to be, and the unfamiliarity of the scenes increase the difficulty encountered by the subject. Ferenczi (1966) has criticised the nature of Hudson's test material, experimental design, sampling and test administration.

Jahoda and McGurk (1974) also give an excellent critique of the Hudson test, considering the pictures themselves, the questions asked, and the scoring procedures. Comment has already been made on the type of pictures used by Hudson. His questioning procedure (Hudson 1960) gives only three questions, the ones already referred to above. The published version of the test has additional questions: "Can the man see the deer?", "Can the deer see the man?" and "How do you know?" Asking the same set of questions to every picture made for a long and repetitious testing session, and this would certainly not contribute to motivation of the
Jahoda and McGurk also considered carefully the so-called 'replications' of Hudson's work (by Mundy-Castle 1966, Kilbride, Robbins and Freeman 1968, Holmes 1963, and Deregowski 1968), and they conclude that the results are incomparable because of the diversity of pictures selected and scoring procedures used. They set out to test the two propositions emerging from the results of the work they reviewed, namely that 1) Black African children lag behind white children in their acquisition of pictorial depth perception (Hudson 1960, 1962a) and 2) A majority of African primary school children fail to respond to depth cues in pictures (Hudson 1962b, Mundy-Castle 1966, Kilbride et al. 1968).

Primary school children in Scotland and Ghana were tested on the Hudson Test and a black-and-white version of the coloured test developed by the authors and described in the previous section of this Chapter. The new test involved little verbalisation by the subject, who was required to make his response with models placed on a horizontal response board (see Chapter Five for a full description of their testing method). The results with the Hudson test were similar to those obtained earlier by Mundy-Castle (1966) and, on the one class with comparable data, Ofori (1970) in Ghana. In Scotland, the two younger groups of Scottish children did not score significantly different from chance, but those in Primary 6 scored significantly above chance. With the Jahoda-McGurk test, all groups of subjects
Figure 2. Examples of pictures from Jahoda and McGurk 1974c, p.261.
scored significantly above chance; there was a significant culture effect, with Scottish children scoring higher than Ghanaian.

Scores from a small group of adults in Scotland showed similar levels of performance on the two tests but apparently no improvement over the children in Primary standard 6 on the new test. The authors conclude that the new test taps skills which are acquired relatively early and there is therefore little improvement beyond the beginning of primary school, whereas the Hudson test taps an inferential skill and is heavily dependent on verbal understanding; both of these continue to develop well beyond the primary level.

Jahoda and McGurk used the coloured version of their test in a cross-cultural study involving samples from several countries, and they used the black-and-white version in an investigation of the efficacy of different cues to depth in Scotland and Ghana (McGurk and Jahoda 1975). The work with the black and white set will be reported first. This consisted of four series of eight pictures, each series portraying a different depth cue. Each picture showed two figures diagonally positionned, as before, and there were either two 'ladies', two 'girls' or one 'lady' and one 'girl'. The task was to select the appropriate model doll and place it in the correct spatial position on a response board. The four cues were elevation alone (E), elevation plus texture gradient (T), elevation plus linear perspective (L), and all three cues together (M). The subjects were 128
Scottish children from a day nursery and a primary school in Glasgow and 80 Ghanaian children from the Staff Village Primary school attached to the University of Ghana at Lagon. The results showed elevation alone to be the least effective cue to depth, with the other three cues significantly more effective, but not significantly different from one another for the Scottish sample. The M condition was significantly more effective than the T and L conditions for the Ghanaian sample. Their results are presented by age, and as the Scottish and Ghanaian children were not matched for age, it is difficult to make comparisons. However, the authors report that an analysis of variance involving the three subgroups from each sample with years of schooling in common showed highly significant differences between cultures. They stress, however, that even for the youngest subjects (4 years in Scotland, 7 years in Ghana) the scores were significantly above chance. There is reason to suspect that there is something about the Jahoda-McGurk pictures which enhances the tendency to three-dimensional responding.

Before considering the remainder of their findings in other countries through the use of their test, it might be worthwhile pausing to consider the problem.

If one considers the example illustrated in figure 2 of the adult in both the foreground and rearground positions, it becomes obvious that the proportions of the figures above and below the horizon line implied by the termination of the texture gradient are not equal. This offends a rule of perspective drawing dealt with in the first section of this
chapter, which is that for drawings of two figures of equal height, the proportions of each above and below the horizon line are constant with increasing distance. The greater proportion of the rearground figure above the implied horizon makes that figure appear larger, and therefore increases the tendency for it to be responded to as 'adult'. Only two sets of pictures have strongly implied horizons, the two with texture gradient, and if horizon information was enhancing the accuracy of size scores, significantly more accurate size scores would be expected for those two sets than for the sets with only elevation and linear perspective. The authors did find significantly greater accuracy of size scores with the addition of texture gradient to elevation alone, but they also found that the addition of linear perspective increased accuracy to the same extent. This point remains open to question.

A more extensive investigation was conducted in several countries using the coloured version of the test (Jahoda and McGurk 1974a and b). Although this thesis is not concerned with perception of depth in coloured pictures, their findings will be briefly summarised. The test involved essentially the same task as before, but there were only three sets of test pictures; the 'grass' condition had only the cue of elevation, the 'path' condition had, in addition, the linear perspective cue provided by a path along which the figures were walking; and the 'fence' condition had an additional linear perspective cue provided by the fence next to the path. The fence gave an additional
comparison measure of height of the figures providing that
the simple assumption was made that the height of the fence
was invariant. Testing procedure was as before, and samples
of Scottish, Zimbabwean and Hong Kong urban and boat
children were compared. In Scotland there was a significant
main effect for age (size scores) and a significant increase
in accuracy with increase in the number of cues to depth.
The age effects were not found in the two Hong Kong samples,
but a main effect for schooling was found in the Zimbabwean
sample. The effect for condition was significant in all
four samples. The absence of main effects for age in the
Hong Kong samples is surprising. For the boat children, it
could be the lack of education - the authors do not give
exact information about the school status of the boat
children, but do say that the children do not usually start
school until age seven, if at all.

What is important in the present context is that the
Zimbabwean children with four years of schooling were not as
backward in their utilisation of pictorial cues as
postulated by Hudson. Their size scores were of the same
order of magnitude (although slightly lower) than those of
the eight-year old Scottish children. Obviously, no direct
comparison can be made with Hudson's results because of the
different testing procedure and pictures. It can be
suggested that the tasks are of a different order of
difficulty, Hudson's pictures being highly impoverished and
unfamiliar, those of Jahoda and McGurk being more realistic
and including the use of colour and solidity of figures.
Using a different technique, Shukla and Sinha (1974), Sinha and Shukla (1974) separated the various pictorial cues to depth in seven subtests of black and white drawings. They made sets of five cards for each of seven cues: interposition, relative size, texture gradient, shading, linear perspective, aerial perspective and multiple cues. Two points on each picture were shown to S and he was asked to say which of the two looked farther away. Six pairs of points were indicated for each picture. They found that cues of interposition, relative size and texture gradient were used more effectively by the younger children. With increasing age came more effective utilization of linear perspective, aerial perspective and shading, but these remained less effective than the other three. Half of their subjects were orphanage children and the other half were from a nursery school and the results showed that, while the youngest children (3 to 4 years) from both environments were almost equally lacking in proficiency (scores for 4 of the depth cues were below chance level), the nursery school children improved faster than the orphanage children with age. Shukla and Sinha made no attempt to compare performance on their own set of pictures with performance on any others. Auld (1973), using only three of Shukla's pictures in each set, found that Scottish Ss at all age levels (4 years-adult) scored significantly above chance on all cues except for the 4 year olds on aerial perspective and the 4-5 year olds on shading. He found that the cues were used in the following developmental order: texture,
linear perspective, multiple, size, interposition, aerial perspective and shading. In general the Scottish children he tested performed better than the Indian children tested by Shukla and Sinha. Auld also tested subjects with a modified set of pictures depicting one circle and one triangle, one black and one white, and with linear perspective, texture, overlap and multiple cues. Ss were asked which of the geometrical shapes was nearer. The results did not confirm the findings with the Shukla material for the young children, and there was no significant influence of cues for the 4 year olds. Post-tests were performed in order to find out if subjects understood the instructions and the 4 year olds' performance on the modified test was found to be related to their comprehension of the concept of 'nearness'.

Summary

Western adults are highly accurate in their estimations of size and distance in photographs, both under binocular viewing conditions and under restricted conditions of monocular viewing with the head stationary. They thus display an ability to pay attention to the monocular, or static, depth cues and use them to estimate size and distance. Western children have been shown to be sensitive to some cues to depth in pictures. Linear perspective has been shown to elicit responses indicating pictorial depth perception in children as young as 3 years of age when the
drawing was faithful to the real scene and the cue was indicated by more than just two lines. Olson's (1975) results indicate that 3- and 5-year old children are sensitive to interposition and height in the picture plane. Children can also use shading and shadows as cues to depth but their judgements are more sensitive than those of adults to the orientation of the picture.

Cross-cultural studies have on the whole indicated a lesser responsiveness to depth cues by non-Western than Western subjects. However, part of this difference appears to lie in the type of picture used in testing non-Westerners. Hudson's test has been widely used, both in its original form and in modified versions. Criticisms of the Hudson test were presented, and it was shown that modified versions of the test have produced greater perception of depth than the original, by using more familiar content and by alterations in the wording of the questions. It was concluded that the Hudson test taps rather sophisticated pictorial skills and is therefore not a suitable indicator of whether subjects are able to perceive pictorial depth. However, this does not invalidate the comparisons made with the test, as long as the level of skill required is born in mind. There have been indications that individuals from isolated or less advantaged surroundings have greater difficulty with the test, and this indicates a high level of pictorial sophistication among the advantaged.

Deregowski's (1968) construction task and the
Jahoda-McGurk (1974) test both elicited greater evidence of pictorial depth perception than the Hudson test, but Deregowski found more 3-dimensional responses among the Zambian schoolboys he tested than among the less educated domestic servants, and Jahoda and McGurk found greater accuracy of size judgements among their Scottish Ss than among their Ghanaian Ss. The cross-cultural replications performed by Jahoda and McGurk (1974a) showed that Zimbabwean children displayed evidence of perception of pictorial depth, although their estimations of size were rather less accurate than those of the Scottish and urban Hong Kong children tested.

There is room for further work on the relative efficacy of depth cues in eliciting pictorial depth perception in non-Westerners, and for a further consideration of the pictures and procedures used in the above studies, in order to unravel the features that lead to one test eliciting fewer responses indicating perception of pictorial depth than another.
CHAPTER THREE

Constancy effects with objects and pictures

Some of the data on perception of size and depth in pictures has been gathered in work on size constancy effects. It is therefore appropriate to summarise the work on constancy effects in pictures. However, as the work is fragmented, it is helpful to do this against a background of the development of size constancy of objects in the real world.

The first part of this chapter briefly summarises the work on the development of size and shape constancy in Westerners. Work on size and shape constancy in Africa is then reviewed, and the third section deals with the work on size constancy in pictures. Finally, Deregowski's findings from experiments on implicit constancy are presented.

Size and shape constancy

Wohlwill (1960) summarised the early work on the development of size and shape constancy. He cites a number of studies which show that size constancy increases with age, although several variables (instructions to the subject, distance and separation of the test objects, adequacy of cues to depth) may affect the degree of
constancy. Beryl's (1926) careful investigation, using the method of constant stimuli and including a variation of the distance between standard and variable is particularly interesting because it includes results from children aged 2 years up to adults. The results show a fairly regular trend towards increasing constancy with age, with 10 year old children and adults reaching near perfect constancy. There was no trace of overconstancy in the adults, but the experimental conditions of standard near and variable far, tend to reduce constancy. Beryl found a loss of constancy in young children with increased distance of the stimulus object. This finding is substantiated in a later study by Zeigler and Leibowitz (1957).

One important variable in size constancy judgements appears to be the position of the standard and the variable relative to the subject. Akishige (1937) and Piaget and Lambercier (1943b, 1951a and 1956a) found greater constancy when the standard was in the far position. Another important variable is the instructions given to subjects (Gilinsky, 1955; Carlson, 1962; Epstein, 1963; Carlson and Tassone, 1967). 'Objective' instructions stress the actual physical size of the standard object and subjects are asked to match the variable to the object's actual size. 'Retinal' instructions stress the size as it appears to be at the eye, an object at a distance looking smaller than a nearer object. Gilinsky (1955) found that 'objective' instructions gave matches in size which increased with
distance, exceeding size constancy, whereas 'retinal' instructions gave matches which decreased as distance increased. The function for the latter was intermediate between the function for size constancy and the function for matches of retinal image or visual angle.

An indication that young children can not vary their matches according to instructions comes from a study by Rapoport (1967) who found only one size matching function with two different sets of instructions for young children, with the emergence of two functions at about 12 years of age.

Tronick and Herschenson (1979) assessed children's ability to distinguish real from phenomenal size in a task using the two arcs of the Jastrow illusion. By extensive questioning, the authors were able to divide the children, aged four to five-and-a-half years, into 'Realists' who could discriminate real from phenomenal size, and 'Phenomenalists' who couldn't. In a size constancy task, using both 'objective' and 'phenomenal' instructions, the 'Phenomenalists' performance was not significantly different from that of the 'Realists'. The authors concluded that the Phenomenalists responded in the same way to the two sets of instructions because they could not distinguish between them; the Realists could distinguish between them, but still did not respond differently because for them there was no basis on which to distinguish real from apparent size. They suggest that all the children
perceived size constancy up to distances of 9 feet solely on the basis of visual information.

Bower's (1964, 1965) work with premotor infants suggests that they are able to respond to real size and real distance of objects. He also found (1971) that cues provided by binocular parallax and motion parallax were the most effective in eliciting real size responses. However, experiments by Day and McKenzie (1977) fail to support Bower's findings that very young infants display size constancy, but they agree that it develops during the first year (McKenzie, Tootell and Day, 1980). As these experiments are not central to the theme of this thesis, they will not be reported in detail.

To summarise, then, size constancy may be present to some degree in infancy, and in Westerners it develops further during childhood. It is greater when objects are relatively close to the subject and when the variable is closer than the standard. That cues to distance are necessary for the operation of constancy has been shown by Holway and Boring (1941) and Hastorf and Way (1952). Hastorf and Way found that judgements of size were reduced from normal size constancy to visual angle judgements when subjects viewed an object monocularly and in a darkened room. With binocular viewing, full cues to distance and with the test objects near the subject, constancy is almost complete at around 5 to 6 years of age, and adults then exhibit overconstancy. When viewing is restricted or the
objects are distant, constancy is suppressed. In older children and adults, constancy is least when instructions are given to match for retinal size and greater under 'objective' instructions.

**Cross-cultural studies of size and shape constancy.**

There have been rather few cross-cultural studies of constancy effects. Thouless (1933) found that a group of Indian students studying in Britain showed a greater tendency to respond to the true shape and size of the object than British students. Beveridge (1935) also found greater shape constancy in West African college students (from what were then the Gold Coast and Togoland) than European students. As Beveridge pointed out, the fact that the African students were studying drawing would tend to reduce the difference in constancy between the two groups, and the difference is probably greater than would appear from his results. In all these groups, the phenomenal regression was greater for size than for shape, although in Beveridge's sample of West Africans, the difference is very small.

Myambo (1972) carried out a study of the influence of education on shape constancy in Malawi. She compared shape constancy in adult groups of educated Senas, uneducated Senas and educated Europeans as well as in uneducated Mang’anja children. The apparatus and testing procedure was similar to that used by Meneghini and Leibowitz (1967).
Subjects viewed a white plastic disc at various angles of inclination and were asked to choose one of a series of graded ellipses as representative of the perceived shape. Subjects were instructed to "...find one (object) that looks the most like the shape you see in front of you." The author does not report on the order in which the comparison objects were presented.

Results showed that uneducated Senas exhibited high shape constancy, educated Senas had rather lower shape constancy, and educated Europeans least of all groups. The inter-group differences were statistically significant.

There were four groups of Mang'anja subjects, ranging from 5 to 20 years of age. The youngest children were not attending school, and the oldest group had received only an average of 2.1 years of schooling. Results showed that all age-groups of subjects were similar in exhibiting high shape constancy; there was no change with age. As the author points out, it is not possible to determine whether the results derive from a different interpretation of instructions by the educated and uneducated subjects or are an indication of a true difference in perception. However, Myambo's results do agree with those reported above from Thouless and Beveridge.

Beveridge (1939) went on to investigate picture preference by Gold Coast students. Thouless (1933) had argued that certain features of Oriental art, "the absence of shadows, and the partial or total absence of perspective"
are probably due to the fact that Orientals have a large tendency to phenomenal regression. Beveridge reasoned that African students, who also exhibit a large tendency to phenomenal regression, might prefer Oriental art to Western art. He found, however, that this was not so; and an interesting feature of his findings lies in the reasons given by the subjects for liking the Western art. "The most important," he writes, "seemed to be the illusion of reality." Examples of comments made by subjects are "The work does not look flat", "Anybody looking at the picture thinks that parts of the paper are bulging out."

In passing, it is interesting to note that Beveridge (1939) must have conducted one of the earliest field-dependence studies. He reports that he asked Ss to stand in a cupboard which was then tilted to an angle of 25 degrees. Through one wall of the cupboard passed a stick, which S was asked to tilt until he considered it to be horizontal. African Ss exhibited less reliance on visual cues than Europeans.

In a study of the Knysna forest workers (an isolated group of whites in South Africa), Mundy-Castle and Nelson (1962) included an assessment of size constancy of black labourers, white nursery school children, and staff of the National Institute of Personnel Research in addition to the Knysna forest workers. Subjects were asked to match an adjustable triangle, 3 metres away, with a fixed triangle 1.5 metres nearer, and were instructed as follows: "When the
further triangle seems to be the same size as the nearer, stop it by pressing the button." Each subject performed two contracting and two expanding trials, alternately. Results indicated that black labourers, white nursery school children and the (white) Knysna forest workers tended to exhibit underconstancy, whereas the staff of the Institute exhibited overconstancy. When tested with Hudson's Pictorial Depth Perception Test, none of the forest workers displayed consistently three-dimensional responding. The authors explain their results in terms of a relatively smaller conceptual influence upon perception in the former three groups.

Wendy Winter (1967) tested two groups of staff at the National Institute of Personnel Research, one being matriculated Europeans, the other being Bantu who had at least completed Primary school. She found no significant racial differences. The results were compared with those from a previous test on Bushmen, locomotive drivers and Optometrics students, and in order of decreasing constancy they emerged thus: Bushmen, NIPR Europeans and Bantu, Bantu locomotive drivers, white students of optometrics. The high constancy of Bushmen was suggested to be a result of experience in estimating distances while hunting in the open land of the Kalahari. This suggestion is consistent with Turnbull's (1961) observation that the BaMbuti pygmies of the Congo, who inhabit dense tropical forests, exhibit a breakdown in constancy scaling when viewing objects at a
great distance. Turnbull cites the example of one BaMbuti who was taken from the forest and shown buffalo at a great distance - the man thought the buffalo were insects.

Size constancy in drawings and photographs.

Accuracy of size judgements in the visual field is in general enhanced by information for distance. In a photograph or drawing, some important cues to depth are absent and additional information for flatness exists, therefore it is to be expected that size constancy will be reduced: but does it operate at all?

Winters and Baldwin (1971) found size constancy already existed by 4 years of age when judgements were made under restricted cue conditions of the sizes of circles in a 3-D display, and that it developed further between the ages of 6 and 10 years. No size constancy was found in the same subjects when the judgements were made in response to photographs of the same 3-D displays.

Similarly, Leibowitz, Bussey, and McGuire (1957) found very little size constancy in response to photographs of objects in comparison with judgements made in response to the objects themselves. Shape constancy, however, was reduced by less than 50% in the photograph. They also found no difference between monocular and binocular observation of the photographs, whereas binocular observation yielded greater size and shape constancy than monocular observation.
for test objects. On the other hand, Wohlwill (1965) found that children were able to make reliable distance judgements in photographs containing an enriched field of cues.

Kubzansky, Rebelsky and Dorman (1971) tested children aged 3 to 6 years with a series of 9 boxes ranging from about 2 inches to 5 inches on a side, and with a series of photographic slides of the same boxes. The near stimulus was 4 feet from the subject, and the far stimulus was 14 feet from the subject. The children were asked to point to the bigger of the two stimuli. The 3-year-olds made more errors than the 5- and 6-year-olds who were about equal. All age groups made more errors in response to the photographic slides than to the objects.

In general then, size constancy in response to objects in photographs develops rather later than size constancy to 3-D displays, and is influenced by pictorial information for depth.

That judgements of size of objects in photographs and drawings varies independently of judgements of distance has been demonstrated by Smith (1958b) and Hayes and King (1967). Hayes and King also found an effect of instructions on size and distance estimates of stimuli presented on a two-dimensional linear perspective drawing: half of the subjects were given preliminary instructions that they were to judge the apparent size and distance of the objects, and all subjects were then asked questions designed to elicit phenomenal size estimations (eg. "Do the targets appear the
same size or does one appear larger than the other?"). The subjects who had received the preliminary instructions gave larger estimates of the size of the pictorially more distant object.

Smith's subjects viewed reproductions of Gibson's stake photographs (see Chapter Two) monocularly from a distance of either 38.1cm or 127cm. In addition to the complete reproductions, two impoverished prints were made. In the first of these, all detail except the standard and variable stakes was deleted; in the second, shadows of the stakes were added to the impoverished print. Before testing, all subjects were instructed that they would see photographs of a large field stretching away for a long distance and finally merging into hilly country near the horizon. Subjects made size matches of the standard and variable stakes in both complete and impoverished photographs, judged the distance of the standard stake and estimated its height in feet. For both types of photograph, judgements of the distance of the standard stake varied as a function of the distance of the photograph from the viewer, but judgements of size were nearly the same under the two viewing conditions. The mean size of the variable stakes was 175.3cm, and judgements of stake-size were slight underestimations; the mean for the picture viewed at 38.4cm being 174.8cm, and that for the picture viewed at 128cm being 173.8cm. Judgements of size in the impoverished photograph were significantly greater underestimations.
(136.8 and 146.5 cm) and were significant departures from visual angle matches. Metrical judgements of size were overestimates of the size of the mean of the variable. When compared with Gibson's (1947) results from a similar study in which the same photographs were viewed binocularly, the mean estimates with monocular viewing are lower than those with binocular viewing. The significance of this study lies in the degree of accuracy exhibited in making size judgements and in the fact that, even without texture gradient, subjects were able to make a reasonable estimate of size. Mean estimates without texture gradient were underestimations of the height of the far stake and there was greater variability of judgements than with the texture gradient.

Weinstein (1957) also used the stake photographs, and his subjects made height matches under unrestricted viewing conditions. In a set of glossy prints, all detail except the test stakes was eliminated. Groups of subjects with and without practice made height matches, all subjects being instructed as to the nature of the photographs. Weinstein's findings were that the variability of size-matches increases with the distance at which a far stake is judged, and that the continuous texture-gradient of a ground-surface is not a necessary condition for size-constancy. The importance of the fact that the adults were specifically instructed that they would see a photograph of a field stretching away in the distance must not be overlooked. As mentioned above,
such instructions would be expected to induce a three-dimensional attitude, which might override the effects of individual pictorial depth cues. Thus, Newman (1971) found a significant influence of texture density gradient on relative distance judgements. Subjects were required to make monocular judgements by moving a marker to the apparent physical mid-point between two other fixed markers.

Implicit-shape constancy

Although this thesis is concerned primarily with size-distance relations in pictures, some work on shape constancy is peripherally relevant, because it is elicited by perception of pictorial depth.

Deregowski (1976a) refers to a picture in R. L. Gregory's 'Eye and Brain' (p. 173) which depicts a boy with a hoop. The hoop is drawn as an ellipse, but is perceived as circular; evidence for the 'real' shape of the object has to be derived from ambient cues, thus implicit constancy is elicited by the context. Deregowski investigated implicit constancy by presenting subjects with drawings of pattern figures on cubes ('implying cubes'): after viewing the figures, subjects had to indicate which figure they had just seen by choosing from series of 5 response cards. One of the response cards was identical with one of the geometrical patterns used, and the other four were derivatives of this
pattern obtained by varying the angle from the horizontal. Subjects were also shown the patterns alone ('plane' stimuli), without the cube background, and asked to select the pattern they had seen.

Deregowski tested Bukusu (West Kenya) and Buale (Ivory Coast) schoolchildren who had an average of 8.2 and 6.8 years of schooling respectively (and had an average age of 17.4 and 13.1 years respectively). No significant difference was found between the Bukusu and Buale groups and the results were therefore combined. Significant differences were found between responses to the 'cube' and 'plane' stimuli, with the pattern selected in response to the cube stimuli indicating greater implicit constancy. A control was run in order to check that the effect had not been produced by the cube making recognition more difficult.

Deregowski (1976b) compared the above results with results obtained from a similar study in Scotland. The Scottish subjects were 12 boys and 12 girls from the third grade of two Primary schools in a Scottish town, and were 7-8 years old. Half the subjects were tested with the 'implying cube' and the remainder with the plane figures. Significant differences were found between responses to the 'cube' and the 'plane' figures, with greater implicit constancy displayed with the cube. Comparison with the African samples revealed a significant difference between the African and Scottish children on the cube, the African sample displaying less implicit shape constancy.
In his African study, Deregowski also tested the hypothesis that subjects who show a relatively greater tendency to respond to implicit-shape constancy, also show other evidence of pictorial depth perception more readily than those Ss who exhibit a lesser influence of implicit-shape constancy. Pictorial depth perception was assessed by a construction task in which subjects were given a quantity of rods and plasticene balls and asked to build models of three figures shown in drawings. Results showed that the three-dimensional interpreters of the drawings were the ones whose scores showed a greater tendency towards implicit constancy.

![Stimulus drawings](image1)

*Stimulus drawings: (a–c) Three of the six patterns used 'drawn on sides of skeleton cubes', (d–f) The other three patterns. Each pattern was drawn both on its own and 'on a cube'. Two sets of six stimuli were thus obtained.*

![Response drawings](image2)

*Response drawings - main set. Six variants of one of the stimulus drawings differing in magnitude of angle A, and having all the lines which formed angle $A = 0^\circ, 7.5^\circ, 15^\circ, 22.5^\circ$ and $30^\circ$.*

Figure 3. From Deregowski, 1976b.
Summary

Size constancy in Westerners increases during childhood and is near perfect by about 10 years of age, given that the objects are reasonably close and that cues to depth are plentiful. Adults exhibit overconstancy under 'retinal' instructions with plentiful cues to depth. Educated non-Western adults tend to exhibit greater constancy than Western adults, and uneducated adults tend to exhibit greater constancy than educated adults. There are exceptions to this progression but the effect of the environment and the development of specific skills relating to the estimation of size-at-a-distance have been postulated to influence the development of constancy.

There are suggestions of a link between constancy scaling and the perception of depth in pictures. Mundy-Castle and Nelson's (1962) findings suggest i) that good constancy implies a lack of attention to the retinal angle and ii) that a lack of perception of pictorial depth is related to accurate constancy scaling. Deregowski (1980) cites a study by Bush and Culwick (undated) who compared Europeans, Tanzanian petty officials and domestic servants, and a group of subjects of mixed Arab-African descent on a shape constancy task. They found significantly higher constancy in the African group than in the other two groups. The Arab-African group were not exposed to much pictorial material in the course of their education, yet, unlike the
African group, had no difficulties with pictorial perception.

Deregowski's (1976a and b) work suggests a link between implicit constancy and pictorial depth perception, with groups of subjects who display implicit constancy also displaying greater pictorial depth perception. At this stage, however, it is not possible to say which comes first, implicit constancy or the perception of pictorial depth.

When a constancy scaling mechanism operates on the perception of the size of a distant object, it results in the more distant object appearing larger than indicated by the retinal angle it subtends. If depth is perceived in a picture, a similar effect could occur, so that of two objects of equal drawn size, the pictorially more distant would appear the larger. As has already been shown, depth is perceived when cues to flatness are ignored. If this is done, constancy could operate, whereas when a picture is treated as a representation of two-dimensionality, constancy scaling would not operate.

The only study of constancy carried out in Malawi (Myambo 1972) showed that higher shape constancy was exhibited by uneducated Malawian adults than by educated Malawian adults, and that educated European adults exhibited least constancy of all three groups. If a negative correlation does exist between constancy and pictorial depth perception, it would be predicted that uneducated Malawians would show least evidence of pictorial depth perception,
educated Malawians would show greater evidence and educated Europeans most evidence of pictorial depth perception. Experimental findings to be reported in Chapter Five support this prediction.
CHAPTER FOUR

The literature reviewed in the previous chapters indicates that much has still to be learned about those characteristics of people and pictures that promote three-dimensional picture perception. Western adults, who have been exposed to drawings and paintings and to motion pictures, have apparently absorbed the conventions of picture viewing and interpret pictures relatively accurately. People who have not received a pictorial education do not read pictures with such facility. From both a theoretical and an educational standpoint, it would be useful to know more about both the features of experience and education and the aspects of picture construction which promote the perception of pictorial depth.

If people who have not been exposed to drawings and paintings recognise objects in a picture, it implies that the picture contains information identical with or sufficiently similar to the optic array from the real object for the picture to be treated as representing the real object. The work of Hochberg and Brooks (1962), Jahoda et al (1977) and Deregowksi, Muldrow and Muldrow (1972) showed that pictures of familiar objects are recognised by subjects who have never received any pictorial education and who have received little or no exposure to pictures. Education thus appears to be unnecessary for the identification of drawings.
of familiar objects, and it can be concluded that this is because the optic array from the pictures was sufficiently similar to the optic array from the real objects.

A similar line of reasoning extends to the perception of depth in a picture. If pictorially uneducated subjects perceive depth in a drawing, it would imply that the drawing contains information identical with that from a real scene. If the drawing is made according to the rules of pictorial perspective, the implication would be that the rules are not purely conventional. Very little of the research reviewed has examined the perception of pictorial depth in subjects who have not been exposed to pictures before. Hudson (1960) and Deregowski (1968) both made comparisons between samples of educated and uneducated subjects, and they found very little evidence of pictorial depth perception in the uneducated. However, the Hudson pictures can not be considered familiar scenes, nor do they obey the laws of perspective drawing. In the same study, Deregowski found greater evidence of pictorial depth perception by the uneducated subjects in response to his diagrams of geometric figures. Other research has shown greater three-dimensional responding to pictures of familiar scenes (Omari and MacGintie 1974, Leach 1975, Hagen and Johnson 1977, Silliman 1976), but all of the subjects in these experiments were schoolchildren. In the present study, uneducated children were tested for perception of pictorial depth in a familiar scene and their performance was compared with that of
schoolchildren of the same ages.

In Malawi, as in many other developing countries, a substantial proportion of the population do not receive schooling, and many of those who complete Primary school do not go on to Secondary school. In the course of his education, the schoolchild is confronted by numerous drawings and diagrams which are used as teaching 'aids'. For the teacher, these illustrations enrich his teaching and convey information rapidly, but their usefulness is lost if the students do not understand pictorial information. In many cases, the pictures are used to illustrate new and unfamiliar material, and in addition the laws of perspective may have been violated. Now the student must use his knowledge of pictorial interpretation in order to understand the picture, but his knowledge may not be adequate. The villager is not often required to use pictorial materials, but there are occasions when (s)he, too, is confronted, for example, by posters devised by health and agricultural workers. There is thus a practical reason for wanting to know whether the unschooled are able to interpret depth relations in a drawing.

At present, there is no formula for a 'good' poster, and all posters have to be field tested. It was hoped that in a modest way the present research might be able to provide some guidelines by revealing some of the characteristics of people and of drawings which facilitate pictorial depth perception. The major focus is on the
pictorial content, and both the efficacy of certain depth cues in eliciting pictorial depth perception and the influence of content familiarity are considered. The age, sex, schooling and home background of subjects were considered as variables which might influence pictorial depth perception. The influence of school and of home background are diverse, and the ways in which either of them might enhance perception of pictorial depth are many. Thus, each was treated in a global fashion, in order to first ascertain whether either was associated with perception of pictorial depth. In order to this, children in school were compared with children of the same age who had never attended school, and children whose parents had received a certain amount of schooling were compared with children whose parents had received little or no schooling. Comparisons were also made between males and females in all age groups.

A general principle guiding the research has been that of Cole, Gay, Glick and Sharp (1971), who stated:

"If there is a general principle to be gleaned from the method upon which our work is based, it derives from our belief that the people we are working with always behave reasonably. When their behavior appears unreasonable, it is to ourselves, our procedures, and our experimental tasks that we turn for an explanation."

In the present context, when subjects do not exhibit pictorial depth perception, it is the drawings, procedures and experimental tasks that have been questioned and modified in the search for the conditions which elicit
greater pictorial depth perception. Several different testing procedures have been used, and none of them are new. For the main part, the alterations have been pictorial rather than procedural, but some procedural modifications have been made as well.

It is possibly true that if colour photographs had been used, many of the problems presented by a failure of pictorial depth perception would not have arisen. However, there were strong technical reasons for not using colour photographs. There were no facilities in Malawi for processing colour films and they had to be sent to Johannesburg (South Africa) for processing. The cost was also prohibitive for didactic use. There were facilities at the University for processing and enlarging black-and-white film, but as such facilities were not generally available, the present research focussed on black-and-white drawings, although photographs were used in some of the experiments.

**Experiment 1**

Many observers express the view that the pictures in the Hudson Test are highly stylised and unnatural. Some observers who perceive the pictures as 3D representations arrive at their answers to the test questions by a process of logical inference rather than from a subjective perception of the relative nearness of the objects. The animals were not very familiar to Malawians, and as
discussed in Chapter Two, it may well have been that Hudson's findings of poor pictorial depth perception in Africans were in part at least a result of the unfamiliarity of form and content of his pictures (see Figure 4).

Figure 4. From Hudson 1960.

An attempt was made to construct pictures similar in layout to those of Hudson's, but with several features altered in order to achieve a more realistic effect. In order to do this, the perspective relations had to be
perspective respectively. At this point it should be mentioned that no professional artist was available to make the drawings, and while the sizes of the huts are the same in all pictures, the figure of the boy varies in size and orientation. The artist attempted to make the orientation of the boy ambiguous, so that he did not appear to be running to one hut or the other. The effect of the orientation on the direction of movement of the boy was investigated in experiment 2.

In order that the changes be only pictorial, Hudson's testing method was used. The full set of questions was asked, except that the identification question (see below) was only repeated when the road was introduced in card 4. The test took about 15 minutes and no problems of motivation were encountered.

In addition to investigating the effect of pictorial changes, data was collected on the subjects' home background and, since both males and females were tested, comment is possible on the Dawson, Young and Choi (1974) hypothesis that the output of testosterone in males between ages seven and eight years accelerates the development of three dimensional picture perception. Maturational changes can not safely be assumed to occur at the same age in different racial groups, but the present study allows for comparison over the range 6-20 years.
**Subjects**

590 subjects were tested, 306 males and 284 females. Approximately 40 subjects from each of four standards of Primary School (Standards 1, 3, 5 and 8) and the four forms of Secondary school (Forms 1, 2, 3 and 4) were tested, half being males and half females. 236 unschooled subjects were tested from the six age categories of 6-8, 9-10, 11-12, 13-14, 15-16 and 17-18 years, with half the subjects in each age group being male and half female. In cases where the child's age was uncertain, attempts were made to ascertain the age in relation to well-known historical and local events. The age range 6-18 years was selected because it was anticipated that it would be the same as the age range of the schoolchildren in the classes selected; however, the mean ages of the schoolchildren were higher than anticipated and their age range was 6-20 years.

In Malawi a child may start Primary school at the age of 5 years, but in practice many do not enter school until they are six or seven. The Primary school has eight standards (one per school year), and when these have been satisfactorily completed, the child may move on to Secondary school. The secondary schools have a four-year curriculum at the end of which the students take the Malawi Certificate of Education, which is their equivalent of English 'O' levels. After two years of Secondary education, there are Junior Certificate examinations, and some students leave with this qualification. Only a few secondary schools in the country
have sixth forms where the students are prepared for the Malawian equivalent of 'A' levels, but many of the students who continue their education after form four enter the University of Malawi degree or diploma programs. The education system has been strongly influenced by the British educational system with, until relatively recently, many British teachers in the schools.

Procedure

Background information was collected on each subject as follows: age, sex, number of years spent at school, school standard or form, occupation of parents and number of older children in the household at school.

The test consisted of four pictures drawn on 8" by 10" white cards. The first was a reproduction of Hudson's card 1, depicting a hunter with a spear and an antelope in the foreground, and an elephant on a hill in the rear ground; card 2 contained the same cues as card 1 and depicted a boy and a hut in the foreground, and a second hut in the centre rear ground; depth cues in both card 1 and card 2 were object size and elevation. Cards 3 and 4 portrayed the same scene as card 2 but had, in addition, the cues of interposition and linear perspective respectively.

For card 1, the set of questions used by Mundy-Castle (1966) were asked:

Q.1. "What do you see in this picture?" (The subject was expected to identify each item; if
necessary the tester pointed to an item and asked "What is this?"

Q.2. "What is the man doing?" If necessary, this was qualified by the question "What is the man doing with the spear?"

Q.3. "Can the deer see the man?"

Q.4. "How do you know?"

Q.5. "Can the man see the deer?"

Q.6. "How do you know?"

Q.7. "Which is closer to the man: the elephant or the deer?"

Question 7 was considered to be the most important in deciding whether the subject was a 2D or a 3D perceiver, but the supplementary questions served to clarify in cases of doubt. For cards 2, 3 and 4 a similar set of questions was asked:

Q.1. "What do you see in this picture?"

Q.2. "What is the boy doing?" If necessary, the tester explained that the boy was running away from the rain.

Q.3. "Which hut is the boy running to?"

Q.4. "Why?" If S did not answer, the tester asked "How do you know?"

Q.5. "Which hut is nearer the boy?"

Q.6. "How do you know?"

Of these, question 5 was considered the most important in
deciding whether the subject was a 2D or a 3D perceiver.

Testing was carried out during the long vacation by Chancellor College students who were either taking an Education course, or Psychology as part of their General Degree. Testers were selected so that there was roughly equal representation from all three regions of Malawi (North, Central and South). They received instruction in the administration of the test and were given a detailed sheet of test instructions, including procedure for arranging a quiet place for testing, setting the subject at ease, following exactly the same procedure for all subjects, as well as the questions to be asked of the subjects. All responses were recorded in full on the answer sheets in the vernacular, and translation was performed later if necessary. Each tester's set of answer sheets was scrutinised upon return, and discussed with him. One tester presented data which was considered unreliable, and his answer sheets were discarded. Each tester selected subjects around his or her home area; the sample was therefore not random, but this system enabled subjects to be tested in their vernacular language where necessary.

Results

**Identification of items.** Subjects were better able to identify the items in the new pictures than in card 1, as is shown by the data in Table 4.1.
Table 4.1. Numbers of subjects correctly identifying all items.

<table>
<thead>
<tr>
<th>Correct</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card 1</td>
<td>372</td>
</tr>
<tr>
<td>Cards 2-4</td>
<td>469</td>
</tr>
</tbody>
</table>

$\chi^2 = 35.3$, $p<0.001$, df=1.

For card 1, the naming of the animals was often incorrect; for example, 'elephant' was identified as 'rhino, pig, hippo, cow, crocodile, monkey, horse, lion, cat, sheep or dog'; the 'spear' as 'stick' or 'arrow' and the 'hill' as 'rock, stone, roots of a tree, road and medicine gourd'. For cards 2, 3 and 4 the main difficulty was with the 'road' in card 4 which was identified as 'rope, telephone wires, lines or a river' and the 'rain' which was thought to be 'stars' or 'flowers'.

Pictorial depth perception.

The percentages of 3D responses to cards 1 and 2 were compared, keeping males and females separate. The results are shown in Figure 7, which gives 3D responses as a percentage for each age group. Chi-square tests were performed for each age group and no significant differences were found between the sexes, so the results were combined.
Figure 6

Percentage of 3D responses to cards 1 and 2 for Males and Females by Age

PERCENT 3D RESPONSES

AGE (YEARS)

FEMALES
MALES
CARD 2
CARD 1

6-8 9-10 11-12 13-14 15-16 17-18 19-20 20+

94a
in order to compare performance on cards 1 and 2. Significantly more 3-dimensional responses were given to card 2 than to card 1 by McNemar's test ($\chi^2 = 8.66$, df = 1, $p<0.005$).

A second test for sex differences was performed on the responses to the new cards. For this purpose an arbitrary criterion was applied whereby a subject was classified as a '3D perceiver' if (s)he gave a three-dimensional response to two of the three cards. Table 4.2 gives the percentage of 3D perceivers by age and sex.

Table 4.2
Percentage of subjects perceiving two of cards 2, 3 and 4 in 3D by age and sex.

<table>
<thead>
<tr>
<th>Age</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8</td>
<td>45</td>
<td>39</td>
</tr>
<tr>
<td>9-10</td>
<td>68</td>
<td>60</td>
</tr>
<tr>
<td>11-12</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>13-14</td>
<td>79</td>
<td>68</td>
</tr>
<tr>
<td>15-16</td>
<td>83</td>
<td>71</td>
</tr>
<tr>
<td>17-18</td>
<td>87</td>
<td>84</td>
</tr>
<tr>
<td>19-20</td>
<td>85</td>
<td>86</td>
</tr>
</tbody>
</table>
The percentages of 3-dimensional responses in the youngest group are depressed by a large number of 'don't know' responses. 25 of the 64 males and 29 of the 61 females gave this response to two or more cards. 4 females in age group 9-10 years gave two or more 'don't know' responses, but in the older age groups there were very few. Chi-square tests were performed to test for an association of 3-dimensional responding with sex, but were not significant at any age group. There is some indication of greater 3-dimensional responding by males in that the male percentages are higher than those of the females in five of the seven age groups, and an overall chi-square test was computed, but was not significant ($X^2 = 1.84, d.f.=1$). There is a steady increase in the proportion of 3D perceivers with age, and a one-tailed test for a linear trend in proportions was significant for both males ($z=3.44, p<0.01$) and females ($z=1.83, p<0.05$).

Table 4.3 gives the percentage of 3D perceivers (based on the same criterion as used above in Table 4.2 of two out of three 3D responses) for the schoolgoers and the unschooled by age.
Table 4.3
Percent '3D perceivers' for the unschooled and schooled by age.

<table>
<thead>
<tr>
<th>Age</th>
<th>No school</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8</td>
<td>38 (64)</td>
<td>44 (59)</td>
</tr>
<tr>
<td>9-10</td>
<td>65 (20)</td>
<td>80 (25)</td>
</tr>
<tr>
<td>11-12</td>
<td>76 (16)</td>
<td>78 (31)</td>
</tr>
<tr>
<td>13-14</td>
<td>74 (19)</td>
<td>74 (42)</td>
</tr>
<tr>
<td>15-16</td>
<td>75 (28)</td>
<td>85 (70)</td>
</tr>
<tr>
<td>17-18</td>
<td>78 (29)</td>
<td>90 (92)</td>
</tr>
<tr>
<td>19-20</td>
<td>—</td>
<td>89 (54)</td>
</tr>
</tbody>
</table>

Numbers of subjects are given in parentheses.

Again the percentages for the youngest age group are affected by relatively large numbers of 'don't know' responses. The percentage of schoolgoers who are 3D perceivers is equal to or greater than the percentage of unschooled who are 3D perceivers in each age group. Chi-square tests were performed for each age group, but none of them were significant. However, an overall chi-square test suggested a significant association between school and 3D perceivers ($X^2 = 5.67, df=1, p<0.02$), but this should be interpreted cautiously because there is an indication (as expected) of an age x perception dependence. The Cochran
Criterion, applied to the proportions (Cochran 1954) was computed and was also significant ($p<0.05$).

The relative efficacy of the different depth cues in eliciting 3D responses is analysed next. Table 4.4 shows the percentage of 3D responses to each of cards 2, 3 and 4 by age.

Table 4.4
Percent 3D responses to cards 2, 3 and 4 by age.

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>Card 2</th>
<th>Card 3</th>
<th>Card 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8</td>
<td>123</td>
<td>41</td>
<td>59</td>
<td>38</td>
</tr>
<tr>
<td>9-10</td>
<td>52</td>
<td>50</td>
<td>77</td>
<td>60</td>
</tr>
<tr>
<td>11-12</td>
<td>47</td>
<td>72</td>
<td>83</td>
<td>64</td>
</tr>
<tr>
<td>13-14</td>
<td>62</td>
<td>66</td>
<td>77</td>
<td>69</td>
</tr>
<tr>
<td>15-16</td>
<td>98</td>
<td>72</td>
<td>81</td>
<td>61</td>
</tr>
<tr>
<td>17-18</td>
<td>123</td>
<td>81</td>
<td>89</td>
<td>70</td>
</tr>
<tr>
<td>19-20</td>
<td>55</td>
<td>78</td>
<td>85</td>
<td>82</td>
</tr>
</tbody>
</table>

There were again a large number of subjects in the youngest age group who could not be classified as 2D or 3D because they gave two or more 'don't know' or 'same distance' responses. Cochran's Q-test (Cochran 1950) was computed on all the data for cards 2, 3 and 4 combined and was highly significant ($Q=87.4$, df=1, $p<0.001$). Q-tests computed on the data for each age group separately are given in Table 4.4.1.
Table 4.4.1

Values of Q from Table 4.4

<table>
<thead>
<tr>
<th>Age</th>
<th>Q</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8</td>
<td>13.06</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>9-10</td>
<td>9.3</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>11-12</td>
<td>8.71</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>13-14</td>
<td>2.7</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>15-16</td>
<td>16.55</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>17-18</td>
<td>13.8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>19-20</td>
<td>1.27</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

It can be seen that of the six youngest groups, only in one case does the test fail to meet the 0.01 level of significance, and that case is significant at the 0.1 level. The lack of any association in the oldest age groups could well be a ceiling effect, as very few two-dimensional responses were given to any card in these groups. Examination of the data revealed that the cue of interposition (card 3) elicited the greatest number of three-dimensional responses in all groups.

The method of Wackerly and Dietrich (1976) was used to make pairwise comparisons of the treatments at each level. This analysis supported the above indication of greater perception of depth to card 3. In the youngest age group (6-8 years) card 3 elicited significantly more three-dimensional responses than either card 2 or card 4,
and in age group 9-10 years significantly more than card 2; in the older groups it elicited significantly more three-dimensional responses than card 4. Responses to cards 2 and 4 were not significantly different at any age. This supports Hudson's (1960) and Shukla's (1973) findings that linear perspective is a less effective cue to depth than interposition.

Finally, the influence of the home environment was considered. Subjects' parents were classified as schooled or not schooled, according to the occupation recorded for them. If a parent's occupation required that he or she had attended school for a minimum of four years, the subject was classified as having schooled parents. This criterion was chosen in order to ensure that the 'schooled' parents were for the main part literate. In 87 cases it was not possible to classify with confidence on the basis of the information available, and these subjects were discarded from this analysis. Inspection of the data showed that almost all the subjects who had not been to school had uneducated parents. On the other hand, approximately half the schoolchildren had educated parents and half had uneducated parents, and it was therefore possible to test the association of parental education with these subjects' performance on the test. Table 4.5 gives the numbers of 3D perceivers according to the educational level of the parents, for the schoolchildren only.
Table 4.5
Numbers of 2D and 3D perceivers
by parental education

<table>
<thead>
<tr>
<th>Parents' perception</th>
<th>3D</th>
<th>2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>No school</td>
<td>138</td>
<td>20</td>
</tr>
<tr>
<td>School</td>
<td>91</td>
<td>35</td>
</tr>
</tbody>
</table>

$X = 10.26$, df=1, p=0.001

The relationship is highly significant and indicates that the home background influences subjects' performance. The means through which this influence is exerted will be discussed later.

It was considered possible that if a child lived in a household with other children attending school, (s)he might be influenced by the presence of school materials and information disseminated by the older schoolchild. A comparison was therefore made between those subjects whose household included other schoolgoers, and those who were the only schoolgoer in their household. This was done keeping subjects with unschooled and schooled parents separate, and the results are given in Table 4.6.
Table 4.6

Numbers of 2D and 3D perceivers by parental education
and number of siblings at school.

<table>
<thead>
<tr>
<th>Perception of subject</th>
<th>Unschooled parents</th>
<th>Schooled parents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of schoolsibs</td>
<td>0 1+</td>
<td>0 1+</td>
</tr>
<tr>
<td>3D</td>
<td>124 79</td>
<td>34 114</td>
</tr>
<tr>
<td>2D</td>
<td>45 29</td>
<td>4 14</td>
</tr>
</tbody>
</table>

\[ X = 0.0096, \quad X = 0.060 \]
\[ \text{df} = 1, \text{n.s.}, \quad \text{df} = 1, \text{n.s.} \]

In neither case is the relationship significant.

Discussion of the results of experiment 1 will be deferred until after the presentation of experiments 2 and 3.

Experiment 2

Introduction

It is possible that the drawing of the boy was not sufficiently ambiguous, in that he could have appeared to be running to the foreground hut, particularly in cards 2 and 3. If subjects perceived this orientation, it might have
influenced their responses and spuriously enhanced the number of apparently 3D perceivers. Two further experiments were therefore run: the first tested the hypothesis that fewer 3-dimensional responses would be elicited by the same (boy) pictures if the stance of the boy was altered so that he appeared to be stationary and facing out of the picture; the second experiment assessed the perceived orientation of the boy and the influence of that orientation, if any, on responses.

**Subjects**

15 boys aged 7 and 8 years and 15 boys aged 13 and 14 years from Zomba Boys Full Primary School. A sample of 15 first year students from Chancellor College who were taking a class in Biology were also tested.

**Materials**

The three cards used in experiment 1 were redrawn with the boy correctly to scale and standing still, facing out of the picture, in the same pictorial location as before. They will be referred to as cards 2', 3' and 4' and are shown in figure 7.

**Procedure**

Testing was done by the author and one of the male assistants who had collected data for experiment 1. The experimenter sat beside the S at a table, and each card was
Figure 7. Modified stance pictures
displayed in turn on a vertical clipboard. After putting the first card in place, E said: 'In this picture the artist is trying to show a boy standing there (indicates) and the rain is beginning to fall; the boy is going to run to the house that is near to him; which house will he go to? Which house is near to the boy?' The three cards were presented in the same order as in Experiment 1 in half the trials, and in the reverse order in the other half.

Results.
The numbers of subjects responding that the foreground hut was nearer are given in Table 4.7

<table>
<thead>
<tr>
<th></th>
<th>7 and 8 yrs</th>
<th>13 and 14 yrs</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card 2'</td>
<td>11 (73)</td>
<td>14 (93)</td>
<td>15 (100)</td>
</tr>
<tr>
<td>Card 3'</td>
<td>15 (100)</td>
<td>14 (93)</td>
<td>15 (100)</td>
</tr>
<tr>
<td>Card 4'</td>
<td>12 (67)</td>
<td>12 (67)</td>
<td>15 (100)</td>
</tr>
</tbody>
</table>

These percentages are certainly not lower than those obtained in experiment 1 (see Table 4.4), suggesting that the orientation of the boy in experiment 1 did not enhance perception of pictorial depth. If anything, the change in
orientation has increased the incidence of three-dimensional responding. Cochran's Q was computed for each age level and showed a significant association of three-dimensional responses with card for the youngest age group (Q=5.2, \( p<0.05 \)). Pairwise comparisons were made using the Wackerly and Dietrich method and the only significant difference was between cards 2 and 3 at age 7-8 years, although there was also a very nearly significant difference between cards 3 and 4 in that age group. The results support the finding of experiment 1, that the younger subjects give a higher percentage of three-dimensional responses to card 3, with the cue of interposition, than to cards 2 or 4.

**Experiment 3**

**Materials**

A set of three pictures was constructed with the figure of the boy in exactly the same positions as in experiment 1 but with the rest of the paper blank.

**Subjects**

21 students from the University of Malawi who were taking the Dip. Ed. degree. Roughly one-third of the class was female, and the average age was 20.6 years.
Procedure

Testing was done by a colleague who was teaching educational Psychology. Subjects were given the three pictures one at a time and were asked to indicate the direction in which the boy appeared to be running by drawing an arrow. If they could not tell exactly where he was going, they were to draw two arrows indicating the limits of his orientation.

Results

A criterion was established whereby subjects' responses could be classified as indicating an orientation of the boy towards one of the huts or an ambiguous orientation. In order to do this, a line was constructed from the centre of the boy's body which bisected the shortest straight line joining the two huts. Travel along the constructed line would not lead to either hut, and therefore responses indicating this direction were classified as ambiguous. Two more lines were constructed from the boy and cutting the edge of the picture one centimetre above and one centimetre below the first constructed line (see figure 7b). Responses indicating an orientation within this band were classified as ambiguous, below the band as 'foreground orientation', and above it as 'rearground orientation'. Using this criterion, estimates of ambiguous orientation are on the conservative side. The numbers of the different responses are in Table 4.8
Figure 7b. Card 2 with orientation criteria marked. Orientation responses falling within the band indicated by the lines from the boy's body were classified as ambiguous, above as background orientation, and below as foreground orientation.
Figure 7b. Card 3 with orientation criteria marked.

Figure 8b. Card 4 with orientation criteria marked.
Table 4.8
Numbers of different types of orientation response to cards 2, 3 and 4

<table>
<thead>
<tr>
<th></th>
<th>Card 2</th>
<th>Card 3</th>
<th>Card 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rearground</td>
<td>9</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Ambiguous</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Foreground</td>
<td>9</td>
<td>15</td>
<td>0</td>
</tr>
</tbody>
</table>

One response to each of cards 3 and 4 was rejected because the subject did not follow the instructions.

The case in which it would be most serious if there were an influence of the boy's orientation is in card 2. This was the one which was compared with the Hudson picture. In fact, however, the figure appears to be quite ambiguous, since equal numbers of subjects perceived the boy's orientation to be to the foreground hut as to the rearground one and four responses were classified as ambiguous.

A problem does exist for card 3 in that the majority of subjects perceive the boy to be running towards the foreground hut. However, for card 4 the orientation is perceived to be towards the rearground hut.

The question now arises as to whether a perceived orientation of the boy does in fact influence subjects' responses. It will be recalled that in classifying subjects as 2D or 3D perceivers most weight was given to question 5.
"Which hut is nearer the boy?" This question could be answered without any reference to the orientation of the boy, but the possibility must be entertained that a perceived orientation to one hut or the other might influence the answer to this question, and for this reason, the responses to the questions were looked at again, and were reclassified.

Answers to questions 3, 4, 5 and 6 (see page 92) given by the unschooled males were reanalysed and were classified as indicating a perceived orientation of the boy, or no perceived orientation. A test for the association of perception of orientation with three-dimensional responding was conducted for each card.

Table 4.9

Numbers of 3D and 2D responses according to the perceived orientation of the boy.

<table>
<thead>
<tr>
<th>Card 2</th>
<th>Card 3</th>
<th>Card 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td>3D</td>
<td>2D</td>
</tr>
<tr>
<td>3D</td>
<td>3D</td>
<td>3D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orientation</th>
<th>3D</th>
<th>3D</th>
<th>3D</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>32</td>
<td>15</td>
<td>43</td>
<td>5</td>
</tr>
<tr>
<td>No orientation</td>
<td>29</td>
<td>15</td>
<td>36</td>
<td>8</td>
</tr>
</tbody>
</table>

Chi-square tests were not significant for any of the cards.

These data suggest that the results of experiment 1 are not invalid. Even where there is some consensus as to the
direction in which the boy is running, this does not necessarily influence the answer to the question "Which hut is nearer the boy?" The findings in any case suggest that the boy in card 2 is not perceived to be running to one hut or the other, and this makes the comparison of this card with card 1 a valid one. The comparisons between cards 2, 3 and 4 are possibly less reliable since there does appear to be a perceived orientation to the foreground hut in card 3 and to the rearground hut in card 4. However, the fact that many Ss gave good reasons for saying that the foreground hut was nearer the boy in card 3, taken together with the findings of experiment 2, lends credence to the interpretation placed upon the findings. This interpretation is also consistent with McGurk and Jahoda's (1974) findings that posture did not influence children's accuracy of size or spatial judgements.

Discussion

Pictorial content, age, education and parental education emerge as variables associated with perception of pictorial depth. The association of the first of these, familiarity, rests on the assumption that hunters, elephant and antelope were indeed less well-known to the subjects than boys and houses. Malawi has little uncultivated land, and elephant and deer, together with many other wild animals are found almost exclusively in game parks, so that very few of the subjects would ever have seen them. Hunters still
exist, but nowadays their garb and equipment is rather more sophisticated than that depicted by Hudson. Work reviewed in Chapter One (eg. Kennedy and Ross 1975, Shaw 1969) showed that drawings of familiar items could be more easily identified than drawings of unfamiliar items, and the results presented here, in Experiment 1, showed that subjects were more accurate in their identification of the more familiar items. The comparison of responses to cards 1 and 2 revealed a significant association of 3-dimensional responses to card 2. Over 50% of subjects from age group 9-10 years onwards gave a 3D response to card 2, and by age 17-18 years, the percentage was over 70; fewer than 30% of any age group gave the three-dimensional response to card 1. That this result was not influenced by the orientation of the boy is evident from the results of experiment 2. Thus the manipulation of familiarity and layout resulted in greater perception of pictorial depth, and this is in accordance with the results of Omari and MacGintie (1974) and Hagen and Johnson (1977), who also found that greater perception of pictorial depth was evidenced by subjects responding to modified versions of the Hudson test pictures than to the Hudson pictures themselves.

The pictorial cue of interposition elicited more three-dimensional responses than the cue of linear perspective, especially among younger subjects. Although it could be argued that the number of three-dimensional responses was increased by the stance of the boy in card 3,
the fact that card 3', in which the boy was in a neutral stance, also elicited more three-dimensional responses than card 4', supports the conclusion. Other studies (Shukla and Sinha 1974, Hudson's white school children (1960), Kilbride, Robbins and Freeman 1968) have also found the cue of interposition to elicit three-dimensional responding at a younger age than other depth cues.

No significant differences were found between males and females in any age group tested, and this goes against the Dawson, Young and Choi (1974) hypothesis that the output of testosterone in males between the ages of seven and eight years accelerates their development of pictorial depth perception. The data presented here covers the age range 6-20 years, and thus allows for a variation in the age at which the output of testosterone might occur in Malawians.

School education is associated with a higher incidence of three-dimensional responding, but even the unschooled exhibit a slight increase in pictorial perception with age. For this latter group, it appears that a plateau is reached during teenage, and it may be that no further increase would be found with more advanced age. The results of experiment 2 show that perception of pictorial depth continues to develop in educated subjects, and here all the University students gave three-dimensional responses to all the pictures. Students at the top of secondary school were for the main part classified as '3D perceivers' when the pictorial content was familiar; however, they can not be
assumed to perceive pictorial depth when the pictorial content is unfamiliar. This is not to suggest that they are incapable of pictorial depth perception in unfamiliar material, but rather that the educator should check the level of comprehension when presenting unfamiliar material, and instruct where necessary.

The home background, as indicated by parental education, is associated with perception of pictorial depth among the schoolchildren. There are of course many factors that would be expected to be associated with educational level, the socio-economic status of the family being the most pervasive, influencing the living conditions, geographical location and nutrition of the child as well as possibly affecting attitudes to education and socialisation practices. However, one would suggest that two factors might be expected to exert the most direct influence: i) a greater exposure to and use of pictures and books in the home, and ii) a greater likelihood of starting school young. This second factor was not investigated in the present research, but it will be discussed in Chapter Seven. The other home background variable investigated was the number of sibs in the household at school which was not associated with pictorial depth perception.

To summarise, it has been shown that both age and education are associated with perception of depth in the 'boy' pictures. Among the educated subjects, the parents' educational level was associated with greater perception of
pictorial depth, and the ways in which this association might have been generated were discussed. Familiar pictorial content enhanced perception of depth at all-age groups tested, and the cue of interposition elicited more three-dimensional responses than the cue of linear perspective among the younger subjects. Even with the new pictures, secondary school students did not give consistently three-dimensional responses. The reason for this could have been the verbal testing procedure. In order to substantiate some of the findings and to investigate the efficacy of other pictorial cues, a testing procedure which was less verbal was sought, and is described in Chapter Five.
CHAPTER FIVE

Introduction

The Hudson test relied heavily on verbal responses, and it was possible that the subjects would have shown greater evidence of three dimensional perception of the pictures had the testing involved less use of language. Omari and Cook (1972) altered one word in the Hudson question "Which is nearer to the man, the antelope or the elephant?" so that half the subjects were asked "Which is farther from the man, the antelope or the elephant?". They found significantly more correct responses among third-grade, lower-middle class children in the United States when they asked "Which is farther...?" Omari and Cook suggest that the use of the term 'nearer' distracting the subject's attention from the background depth cues.

Hagen and Johnson also varied the wording of the Hudson questions and compared "Which is nearer the man, the elephant or the antelope?" with "Which is the hunter aiming at, elephant or antelope?" They found that the former question evoked more than two-and-a-half times the number of 3D responses evoked by the latter question. Children's understanding of the questions cannot be taken for granted, and it was considered possible that their true ability to perceive pictorial depth might have been masked by problems of verbal comprehension. In order to substantiate some of
the findings of Chapter Four and to investigate the efficacy of more pictorial depth cues, a testing procedure which was less verbal was sought.

A method used by Jahoda and McGurk was considered to be appropriate, being almost non-verbal. The test consists of series of eight pictures in which are depicted two figures, one of which might be a 'lady' and one a 'girl' or both of which might be 'ladies' or 'girls'. Subjects were supplied with four dolls (two 'ladies' and two 'girls') and were requested to position the dolls on a response board according to the positions in which they saw them in the pictures. In each test picture, the two figures were diagonally aligned, with one pictorially more distant than the other and the series differed from one another in the depth cues used.

A variation of this test was prepared, using huts instead of female figures. In this part of Malawi, it is customary for a married couple to build a fairly large living hut for themselves, and any very young children would sleep in this hut with the parents. When the children are old enough, a separate 'dormitory' is built for them. The dormitory is smaller than the 'living hut'. Modelled on these huts, series of black-and-white pictures were constructed, similar to the Jahoda-McGurk series and they were tested on subjects from the same age groups as those tested by Jahoda and McGurk. It was expected that a greater tendency to three-dimensional picture perception would be
exhibited than on the test already reported in experiment 1.

**Experiment 4**

**Materials**

Four series of eight pictures were constructed, each series having different cues to depth as follows: series E, elevation on the picture plane only; series ELP, elevation with linear perspective; series ET, elevation with texture gradient; series EAP, elevation with aerial perspective. An example of each series is shown in figure 8, and full sets are in Appendix A. Series E, ELP and ET were chosen because they were combinations used by Jahoda and McGurk, and comparisons with their results would therefore be possible. Instead of combining cues for a fourth series it was decided to include a fourth cue. It was not possible to use superimposition in this task, and aerial perspective was chosen because it has not been included in many studies. Shukla and Sinha (1974) and Auld (1973) found aerial perspective to be an effective cue for subjects over the age of five years.

The living hut was drawn 9cm by 6cm when in the foreground and 6cm by 4cm when in the rearground; the dormitory was 6cm by 4cm when in the foreground and 4cm by 2.7cm when in the rearground. Thus the size of the dormitory was two-thirds that of the living hut and a hut in
Figure 3. Examples of huts pictures

a. Two living huts with depth cue of elevation
b. Living hut - dormitory, with elevation and texture gradient.
c. Two dormitories, with elevation and linear perspective

d. Living hut and dormitory, with elevation and aerial perspective.
the rearground was two-thirds its foreground size. All possible combinations of the two houses were used and two versions of each combination were drawn by reversing the left-right positioning. One set of pictures with only the cue of elevation was prepared, and these were duplicated and used for the other series by adding the lines for linear perspective and the 'grass' for the texture gradient. Aerial perspective was added by chalking over the rearground hut, the horizon line and the cloud with white chalk. This gave a suitably hazy appearance to the more distant part of the picture. A series of training pictures was constructed, in which the two huts were always aligned horizontally.

Subjects

120 subjects were to be tested, 30 in each of the age groups 4-5 years, 7-8 years, 10-11 years and 13-14 years, with half of each age group being schoolgoers and the other half being unschooled. The 4-5 year old schoolgoers were attending one of two play groups in Zomba, while the older schoolchildren were attending the Church of Central Africa Presbyterian (C.C.A.P.) Primary school in Zomba. The unschooled group were drawn from several villages about 18 miles from the town. All subjects were male, except for some of the 4-5 year old playgroup children; girls had to be included as there were insufficient boys. Males were chosen in order to facilitate testing in the rural areas, since there is sometimes a certain amount of reserve, even
amounting to a refusal to be tested, when a male tester approaches young women and girls. Testing for this experiment was performed by a male assistant who was a Psychology student at Chancellor College, and a speaker of both Cewa and Yao, the languages of this area. The tester was trained in the method of testing and was supervised throughout his first testing session and at frequent intervals thereafter. He was provided with a detailed instruction sheet which he could refer to if necessary.

In the school, subjects were randomly selected from a list of names of all the children in the appropriate age groups, which was supplied by the headmaster. Selection procedure in the villages was rather more difficult, the chief escorted us to the villages and introduced us to the headmen, who then provided information on the names and ages of the boys in their village; selection was then made as randomly as possible. Where there was doubt about the ages of the children, attempts were made to relate the birth of the child to well-known historical and local events, but if the age was still very uncertain, the child was not tested.

The town of Zomba nestled at the foot of Zomba plateau which rose about 900 metres above the town, and which was largely uninhabited except by forest workers. The land around Zomba was undulating, with occasional outcroppings of hills and mountains, and was closely cultivated, mainly under subsistence farming, but with some large tobacco farms also. The people in the villages included in this study
were mainly Cewa, a matrilineal group, and the villages were about average for Malawi in terms of economic level, the main crops being cassava and maize; there was little cash cropping.

Procedure

In the school, an empty classroom was allocated for testing. This opened through an archway to a small central quadrangle, as did about five other classrooms. Not all the classrooms had teachers in them all the time and the area was quite noisy, but the students were accustomed to working under those conditions. Pupils passed the classroom quite frequently, so the subject was seated at a table with his back to the quadrangle. Children in the playgroups were tested either in a corner of the playroom or in an adjoining room; again, a familiar but not silent environment. In the villages, a table and chairs were provided under a suitable tree; attempts were made to prevent people looking over the subject's shoulder and making comments by asking spectators to sit in front.

Informal conversation was made in order to set the subject at ease, and it was explained that he would be shown some pictures and it would be rather like a game. The schoolchildren were reassured that the results had nothing to do with their schoolwork and would not be shown to their teachers; the emphasis throughout was on treating this as a game rather than a test. The subject's name, age and school
were recorded on a scoresheet and a clipboard was set up in a vertical position on the table, about 38cm away from the subject, as shown in figure 9. In front of the clipboard was a response board and four model huts, two living huts and two dormitories. In the centre of the response board were marked four spots forming the corners of a rectangle 15.2cm by 10.2cm. It was explained to each subject that in each picture there would always be two huts, either two living huts, two dormitories, or one living hut and one dormitory; he would be asked to say which huts he saw in the picture and then to make an arrangement on the response board just like the one he saw in the picture. His attention was drawn to the model huts and it was ensured that he could identify them. This information was conveyed to the subjects without referring to size, the huts were always referred to by their names. The first training picture was presented and the subject was asked to say which huts he saw. Any incorrect responses were corrected, and it was then demonstrated how the models could be used to represent the huts in the picture, placing them on the appropriate spots on the response board and providing a verbal commentary while so doing. After telling the subject that he was to place the models in the appropriate positions for the next pictures, the models were cleared off the board and the second training picture displayed in place of the first. Correction was made if the subject made an incorrect response, and training continued until a criterion of seven
Figure 9. Diagram of apparatus (not to scale).

Vertical clipboard with test picture

Horizontal response board

models
consecutive correct responses had been made or until 24
trials had been completed.

When training had been completed, the subject was told
that, up to now, the huts in the pictures had always been
located at the positions represented by the two horizontally
aligned front or rear spots on the response board. He was
told that, from now on, the huts might be located at other
positions but that it would be clear from each picture where
the huts were located. Then, using the models, it was
demonstrated how the huts might occupy any pair of the
horizontally, vertically, or diagonally aligned spots.

Before presenting the test pictures, the subject was asked
to demonstrate, with the models, the various positions the
huts might occupy. He was reminded that if he looked
carefully at each picture, he would be able to see just
where the huts were located.

Throughout the testing, the tester maintained a neutral
pose and attempted to be generally encouraging. After
testing was completed, some questions were asked concerning
the identification of the various lines in the picture, and
any points the subjects wanted to raise were discussed; he
was then thanked for his help. Children were rewarded with
sweets, and students with a pencil each.
Design of experiment

There were four series of eight test pictures and therefore twenty four different possible orders of presentation of the series. Fifteen different orders were selected at random from the twenty four, with the constraint that nearly equal numbers of orders started with each series. Each of these fifteen orders was given once in each age and schooling category.

Results

Responses were scored for both size and spatial correctness. If the correct sizes of model were selected and placed on the correct sides of the board, the size score was 1, even if the models were horizontally aligned or aligned on an incorrect diagonal. A spatial score of 1 was given if the two models were placed in the correct spatial position, even if they were not the correct sizes. For each picture, then, a subject could have a size score of 0 or 1 and a spatial score of 0 or 1. The maximum size or spatial score for a series of eight pictures was therefore 8.

Mean numbers of correct size responses for each age and schooling category are given in Table 5.1. There were 30 subjects in the three older groups and 16 in the 4-5 year olds group.
Table 5.1

Mean numbers of correct size responses to pictures having
different cues to depth by age and schooling.

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>Sch</th>
<th>Unsch</th>
<th>Sch</th>
<th>Unsch</th>
<th>Sch</th>
<th>Unsch</th>
<th>Sch</th>
<th>Unsch</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>16</td>
<td>3.6</td>
<td>1.9</td>
<td>3.5</td>
<td>2.9</td>
<td>3.3</td>
<td>2.9</td>
<td>3.5</td>
<td>1.6</td>
</tr>
<tr>
<td>7-8</td>
<td>30</td>
<td>2.9</td>
<td>2.5</td>
<td>2.7</td>
<td>2.6</td>
<td>2.7</td>
<td>3.2</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>10-11</td>
<td>30</td>
<td>1.9</td>
<td>2.7</td>
<td>2.6</td>
<td>2.5</td>
<td>2.6</td>
<td>2.7</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>13-14</td>
<td>30</td>
<td>2.3</td>
<td>2.9</td>
<td>2.5</td>
<td>2.6</td>
<td>3.0</td>
<td>3.2</td>
<td>2.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>

E: elevation, LP: linear perspective, T: texture gradient, 
AP: aerial perspective.

There were no apparent differences between series E, ELP and ET, and they were therefore treated together. A two-way analysis of variance showed no significant main effects for age (F=5.41, df=3,98) and no significant interaction between age and schooling (F=0.86, df=3,98).
Table 5.2
Mean numbers of correct spatial responses to pictures having different cues to depth by age and schooling.

<table>
<thead>
<tr>
<th>Age</th>
<th>E</th>
<th>ELP</th>
<th>ET</th>
<th>EAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sch</td>
<td>Uns</td>
<td>Sch</td>
<td>Uns</td>
</tr>
<tr>
<td>4-5</td>
<td>16</td>
<td>3.9</td>
<td>0.8</td>
<td>3.8</td>
</tr>
<tr>
<td>7-8</td>
<td>30</td>
<td>7.1</td>
<td>3.5</td>
<td>6.7</td>
</tr>
<tr>
<td>10-11</td>
<td>30</td>
<td>6.9</td>
<td>5.1</td>
<td>7.3</td>
</tr>
<tr>
<td>13-14</td>
<td>30</td>
<td>7.2</td>
<td>5.5</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Here there is an interesting trend, with scores increasing with age and with schooling. Performance of the schoolchildren is better than that of the unschooled even in the youngest group. Series E, ELP and ET were again treated together in a two-way analysis of variance and revealed significant main effects for age ($F=12.3$, df=3,98 $p<0.001$), and schooling ($F=25.3$, df=1,98 $p<0.001$), with no interaction ($F=11.17$, df=3,98). The contrast measuring difference between the 4-5 year olds and the other groups was significant ($F=33.47$, df=1,98 $p<0.001$), but that between the 7-8 and 13-14 year old groups was not ($F=3.25$, df=1,98).

The figures for the schoolchildren compare favourably with those reported by McGurk and Jahoda (1975) for Scottish children, whereas the figures for the unschooled children are more similar to those for their Ghanaian samples.
Discussion

The test appears to be tapping two rather different abilities, and the present results suggest that in Malawians accurate spatial responding precedes accurate size responding. However, as other subjects have displayed more accurate size responses on the Jahoda-McGurk version of the test, the content of the pictures and the subjects themselves both merit further investigation.

The most obvious points for criticism in the pictures themselves are the position of the horizon line and the elevation of the rear hut. For a horizontal, flat, ground plane, the horizon line fixes the station point, and is usually drawn for a station point about 5-6 feet high, this being the eye position of a standing adult. The horizon line in these pictures suggests that the observer is standing on a hill, overlooking the houses, which are in turn built on a hill. An alternative interpretation that subjects could have achieved by more or less ignoring the horizon line is that these are diagrams rather than pictures, and they might therefore perceive them as two-dimensional representations even though they were capable of perceiving a picture as a three-dimensional representation. This possibility was investigated further in experiment 5.

If the picture was indeed responded to as a two-dimensional diagram, the subjects would have chosen model huts according to the relative drawn sizes of the
huts. Three of the combinations of huts (living hut in the foreground and dormitory in the rearground, two living huts, and two dormitories) result in the foreground hut being of larger drawn size than the rearground hut. Subjects would therefore place the model living hut in the foreground position and the model dormitory in the rearground position, and in two of the six cases they would be correct, thus earning a score of 2. The fourth combination, of dormitory in the foreground and living hut in the rearground results in two huts of equal drawn size, the subject would therefore select two models of equal size, and earn scores of 0. Total scores would therefore be 2, which is chance responding, and this is what occurred.

Experiment 5

Introduction

In order to ascertain whether the high horizon line and rearground hut tended to depress size scores, series of the drawings were constructed with a less elevated horizon line and rearground hut. The low size scores throughout experiment 4 indicated that there was a possibility of finding chance level scores even with the modified drawings; such scores might be an indication that the test was tapping skills not yet developed by the subjects tested so far rather than a lack of an effect due to the rearground elevation. For this reason, a sample of University
students, known to be capable of pictorial depth perception, was tested. If all four of the original series had been used in the test, together with four new series, the test would have been too long. It was therefore decided to omit the series with the cue of aerial perspective as subjects' comments had indicated that they did not utilise the cue.

Materials

Three new series of huts pictures were constructed, in which the rearground hut was less elevated and looked more natural (see figure 10). They were series E (elevation alone), ELP (elevation and linear perspective) and ET (elevation and texture gradient), and they were tested together with the three equivalent series from experiment 1.

Subjects

15 students from Chancellor College who were taking an Introductory course in Psychology, whose mean age was 19.9 years.

Procedure

Procedure was as in experiment 1. Each subject responded to all six series of pictures, but none showed any signs of boredom. Fifteen different orders of presentation of the series were randomly selected, with the constraint that each series was the first either two or three times. Scoring was as before, and the results are in Table 5.3.
Figure 10. One example of each series of huts pictures having the less elevated rearground hut.
Results and discussion

Table 5.3
Mean numbers of correct size and spatial responses to six series of pictures for Chancellor College students.

<table>
<thead>
<tr>
<th></th>
<th>Greater elevation</th>
<th>Less elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E</td>
<td>ELP</td>
</tr>
<tr>
<td>Mean correct size resps</td>
<td>5.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Mean correct spatial</td>
<td>8.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

These results are very interesting. The spatial scores are maximum for the original three series with the greater elevation of the rearground hut, and only very slightly depressed by for the less elevated series. Statistical tests were not necessary to show that the size scores are significantly higher than those of the 13-14 year old group tested in experiment 1, but there are no significant effects due to elevation. The size scores are perhaps a little lower than might be expected from the McGurk and Jahoda (1975) results for Ghanaian children, (they obtained scores of 3.8, 4.8 and 4.6 for 13-year old schoolchildren in response to depth cues of elevation alone, elevation with linear perspective, and elevation with texture gradient respectively). An interesting feature of the results which is not shown in the table is the range of size scores among the students. Four subjects scored 47 or 48 out of a possible maximum of 48, while the lowest score was 12,
exactly at chance level. For some reason, interpretation of depth cues has not been developed in some students in spite of many years of schooling and use of books. After testing, all students were questioned about the pictures and were also asked whether they had received any art instruction in school. Two of those with the highest scores said they had studied art for two years at secondary school, the other two had received some art instruction at Primary school. Eight of the fifteen subjects said they had no art instruction at school at all, and for some, the instruction had been exercises in the description of pictures, a passive rather than an active method of learning. More than one student voiced the conflict he saw between information for a vertical plane and information that the picture represented a horizontal plane.

Experiment 6

The possibility still remains that Malawian subjects have greater difficulties in pictorial depth perception than their Scottish and Ghanaian counterparts, although the main difficulty could reside in the pictorial content. In order to obtain a European comparison, a sample of European children was tested.

Subjects

15 7-8 year old European children who were attending the local Primary school in Zomba. The sample was matched
as far as possible for years of schooling with the sample of Malawian schoolchildren in experiment 5, but because of the small numbers of European children, a higher proportion of them were in Standard 3 and two were in Standard 4. The children were mainly from middle class families, their parents being on contract to Government departments or the University, or working in a managerial capacity on farms. There were 9 girls and 6 boys.

Materials and procedure

Three series of the original huts pictures, E, ELP and ET were used. Testing was carried out in an empty classroom in the school, and procedure was the same as before.

Results and discussion

Table 5.4

Mean size and spatial scores for 7-8 year old European children for three series of pictures.

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>ELP</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean no. correct size scores</td>
<td>3.3</td>
<td>3.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Mean no. correct spatial scores</td>
<td>7.9</td>
<td>7.9</td>
<td>7.9</td>
</tr>
</tbody>
</table>

There is a significant increase in mean size scores over the Malawian schoolchildren of the same age, but the scores are lower than those obtained for Scottish children by McGurk and Jahoda. The spatial scores show an increase.
over the Malawian schoolchildren, and are almost maximum. A comparison of the scores of the three groups of 7-8 year old schoolchildren tested so far reveals a consistent increase in size scores from the unschooled through the schooled Malawians to the Europeans (see Table 5.1). An analysis of variance revealed a just significant overall school effect (F=3.25, df=2,42, p<0.05). A greater increase in the same direction is evident in the spatial scores, with the sharpest increase being from the uneducated to the educated Malawians. The contrast measuring difference between the Europeans and Malawians is significant for size scores (F=6.4, df=1,42 p<0.05), whereas for spatial scores the significant difference is between the schooled and unschooled (F=46.7, df=1,42 p<0.01).

The possibility was considered that the European children in higher standards might be enhancing the mean scores of the sample, and in order to check on this, the mean scores were computed for children in each standard and for each depth cue. There was no case in which the means were higher for the children in Standards 3 and 4 than for the children in Standard 2. It is therefore unlikely that the greater accuracy of the European children was a result of greater years of schooling per se.
Table 5.5
Mean size and spatial scores for 7-8 year old unschooled and schooled Malawians and Europeans.

<table>
<thead>
<tr>
<th>Size responses</th>
<th>Spatial responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uns</td>
</tr>
<tr>
<td>Elevation</td>
<td>2.5</td>
</tr>
<tr>
<td>ELP</td>
<td>2.6</td>
</tr>
<tr>
<td>ET</td>
<td>3.2</td>
</tr>
</tbody>
</table>

The results give some support to the hypothesis that Malawian subjects find these pictures more difficult to interpret than Europeans; it should be borne in mind that the concept of dormitory and living huts was alien to the European children and only one of the fifteen had ever been in a Malawian village.

Experiment 7
The rather low scores of the European children as compared to McGurk and Jahoda's Scottish sample suggests that the pictures themselves are also, for some reason, more difficult to interpret than theirs. The most obvious difference is that they used human figures as opposed to the huts used here, and in order to test for an effect due to this difference in pictorial content, two series of pictures of figures were constructed and tested on a group of 13-14 year old Malawians.
Materials

Two series of pictures were constructed, using the cues of elevation alone and elevation with linear perspective. In order to ensure that the figures were exactly the same except for their size, a photographic process was employed. A female figure was drawn in such a way as to be ambiguous, such that she could be taken as either an adult or a child. This was a difficult task, and the artist was forced into drawing the figure in the same pose as that used by Jahoda and McGurk (1974a). The figure was drawn in black ink on white paper and then photographed. Three sizes of figure were then produced, 6.5cm, 4.3cm and 2.8cm high. The photographs were then stuck onto white paper in the positions appropriate for each of the eight pictures in a series and rephotographed; two different backgrounds were used, one plain white with only a horizon line and cloud, and the other having in addition two lines delineating a path on which the figures were walking. The horizon line was high and undulating. Four examples are shown in figure 11. Four wooden dolls were provided, the two 'women' being 7.5cm high and the two 'girls' being 5cm high.

Subjects

The subjects were 13-14 year old children attending the Mponda Primary school in Zomba. Fifteen boys were tested by a male assistant in an empty classroom. The subjects were selected at random from a list of 13 and 14 year olds.
Figure 11. One example of each of the four adult-child combinations.
provided by the headmaster.

Procedure

The training and testing procedures were the same as those used in experiments 4 to 6, except that the model figures were described as women and girls. The tester gave alternate subjects series E before series EL, so that half the subjects did series E first and half did series EL first. Otherwise, the testing procedure and scoring was the same as before.

Results

Table 5.6
Mean size and spatial scores for 13-14 year old schoolchildren on the figures task.

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>ELP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean size scores</td>
<td>3.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Mean spatial scores</td>
<td>6.7</td>
<td>7.0</td>
</tr>
</tbody>
</table>

There is a significant increase in size scores over those of the 13-14 year olds in the 'huts' task (T=3.43, p<0.005), and a very slight drop in the spatial scores, which was not significant. The latter is presumably due to the relatively smaller elevation of the rearground figure in relation to the foreground figure, which would make the vertical
separation of the two figures less readily discriminable.

None of the alterations made so far appear to make any very great differences to the size responses of subjects, although size scores for the 'figures' pictures have shown a statistically significant increase over those for the 'huts' pictures. This leads to more fundamental questions concerning the construction of all these types of pictures, and the nature of the difficulties faced in responding to them.

If all the pictures used in the construction tasks reported here and all those used by Jahoda and McGurk are studied for their correctness as perspective drawings, certain deviations are found. In the Jahoda-McGurk pictures, the most consistent of these is the proportions of the figures above and below the horizon line. As Sedgwick (1973) has shown, there is a simple horizon ratio which states that 'the ratio of the height of the object to the height of the point of observation is approximately equal to the ratio of the optic array angle subtended vertically by the object to the optic array angle subtended vertically by the portion of the object that is below the horizon'. This ratio holds for a level, unbounded ground surface, which is the surface suggested by the implied horizon in the black-and-white pictures used by Jahoda and McGurk (1974b and c). In other words, the proportion of a figure of given height above and below the horizon does not vary with variation in the distance of the figure from the observer.
The black-and-white pictures used by Jahoda and McGurk (1974) do not comply with this rule. They give an example, shown in Figure 12, of adults in both the foreground and rearground positions, but the proportion of the rearground figure above the horizon is greater than the proportion of the foreground figure above the horizon. This would suggest a taller rearground figure and predispose the subjects to choose an adult model. They also show an example of a child in the foreground and an adult in the rearground, where the effect is even more striking. The same criticism can be levelled at their 1975 pictures: the adult, drawn with only the head above the horizon when in the foreground as in Figure 13 (d) (see McGurk and Jahoda 1975, p. 284) should also be drawn with only the head above the horizon when in the rearground. That this has not been done can be seen by comparing the adult in the rearground of Figure 13 (b), where the horizon intersects the lower part of the figure's skirt. Thus, again, the rearground adult is placed in such a position as to increase the number of 'adult' responses. The picture which is least often correctly responded to is the adult rear, child fore, and the responses to this picture would be more likely to be correct with their elevated rearground adult. However, the fact that their (1975) results, with only the cues of elevation and linear perspective in which there is no horizon, are similar to those of the pictures with texture gradient goes against the above interpretation.
Figure 12. Examples of pictures from Jahoda and McGurk 1974c, p.261.

Examples of pictures employed under each test condition: (a) child front/adult rear—elevation condition; (b) child front/adult rear—texture condition; (c) adult front/child rear—linear perspective condition; (d) adult front/child rear—multiple cues condition.

Figure 13. From McGurk and Jahoda 1975, p.284.
As size accuracy was not greatly increased by the pictorial changes introduced in the figures pictures, it was decided to turn to photographs of real three-dimensional displays in search of pictures that might enhance size accuracy.

A photograph is a faithful representation of an optic array, and it has been found (eg. Fuglesang 1978) that black-and-white photographs of simple scenes are more readily understood than black-and-white drawings. A set of eight photographs was therefore constructed for the final experiment in this series, the hypothesis being that there would be a significant increase in size scores over the scores for the black-and-white drawings. Two large (1 Kg size) and two small (450gm size) Lactogen (a very widely available dried milk powder) tins were used for the photographs, the design on the two sizes of tins being the same, and the proportions of the tins being virtually the same: the ratio of the diameter to the height of the large tin was 0.86:1 and for the small tin 0.83:1. The distances of the tins from the camera necessary for the large tin in the foreground to subtend a visual angle equal to that subtended by the small tin in the foreground was calculated. Because of the proportionately very slightly greater width to height of the large tin, the distance was calculated so that the area of the tins in the photograph would be equal, and this meant that, in the photograph, the large tin was very slightly shorter than the small tin, but also very
slightly wider.

Experiment 8

Subjects

Ss were 15 students taking a first year course in Biology at Chancellor College, 15 boys aged 13-14 years from Zomba Boys Full Primary School, and 15 boys aged 7-8 years from the same school.

Materials

A set of eight photographs was made of the eight possible arrangements of four Lactogen tins, two being a large size, and two being small. The tins were positioned on flat ground so as to give arrangements similar to those used in the previous pictures. This was done by marking out the four corners of a rectangle 58.4 by 45.7cm, the nearer short side of the rectangle being 2.13m from the camera and parallel to the film. The tins were positioned at diagonally opposite corners, with the picture of the baby on the tin towards the camera. The eight different possible arrangements of the tins were photographed with Agfa film in a Pentax camera; four training photographs were also taken with the tins in the foreground positions. All the photographs were taken at the same exposure and shutter speed. The final prints were on gloss paper (no matt was available) and measured 19.7cm by 12.3cm, and are shown
Figure 14. Photographs of all combinations of the two 1Kg and two 450gm size Lactogen tins used in experiment 8 (reduced size).
in figure 14. The height of the large tin in the foreground position was 4cm. and in the rear ground position 3.2cm; the height of the small tin in the foreground was 3.25cm and in the rear ground 2.6cm.

Procedure

Procedure was the same as for the previous experiments, the subjects being given the four tins that were photographed to place on the response board. Because of the size of the tins, the board was rather larger than that used for the models of houses and figures, being 56cm by 52cm, and the four spots being at the corners of a rectangle 26cm by 22cm. The photographs were presented in the same order as that used for the huts and figures pictures in experiments 4-7.

Results

Table 5.7
Mean number of correct size and spatial scores for photographs by age

<table>
<thead>
<tr>
<th>Age</th>
<th>Mean size scores</th>
<th>Mean spatial scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-8 yrs</td>
<td>3.5</td>
<td>5.9</td>
</tr>
<tr>
<td>13-14 yrs</td>
<td>3.8</td>
<td>6.2</td>
</tr>
<tr>
<td>Adult</td>
<td>5.2</td>
<td>8.0</td>
</tr>
</tbody>
</table>

There is a significant increase in size scores over those
for the huts pictures, but a decrease in spatial scores for
the two younger groups, which is consistent with the
findings of reduced spatial accuracy in response to the less
elevated series of huts pictures as compared with the more
elevated series in experiment 5.

An analysis of variance on the size scores of 13-14
year old subjects on the 'huts', 'figures' and 'tins' tasks
revealed an overall significant difference (F=4.38, df=2,42
p<0.05) with scores on 'huts' being lowest and scores on
'tins' being highest. There was a very significant contrast
effect (F=8.17, df=1,42 p<0.01) between the 'huts' task and
the others.

Discussion

As commented earlier in this chapter, the Jahoda-McGurk
testing procedure appears to tap two different abilities,
namely size estimation and spatial interpretation. For this
reason the spatial score results will be discussed after the
size score results.

The size scores reveal the significance of two factors
on the development of pictorial depth perception, namely
pictorial content and educational background of the
subjects. The term 'educational background' is being used in
a global fashion and is intended to encompass more than
schooling, and to include unquantified factors such as the
home learning environment and culture; no pretence is made
that the relevant features of this background have been
isolated. The comparison between Malawian and European 7-8 year olds' performance on the huts task showed significantly higher size scores for the European children, and this on pictorial content that was somewhat unfamiliar to them. Although this comparison also revealed a significant difference between the performance of schooled and unschooled Malawians, this superiority is only evident in the 4-5 and 7-8 year olds. The lack of an effect of education on size scores in experiment 4 was thought to have resulted from the level of difficulty of the pictures, as size scores were around chance level for all ages. The lack of an education effect might be a baseline effect, since most scores were at chance level. The huts pictures appeared to be too difficult and the reasons for this appear to be the position of the horizon line and possibly the drawing of the houses themselves. The role of pictorial content is evidenced in the increasing size scores of Malawian 13-14 year olds from the huts pictures through the figures pictures to the Lactogen tins photographs.

Turning to the spatial scores, there are consistent trends, with scores increasing with age and schooling. There was a slight, but not statistically significant, depression of spatial scores in the three huts series depicting less elevation of the rearground hut, and a slight decrease in spatial scores for the 7-8 and 13-14 year olds in the tins task.

Taken together, the results suggest that spatial
interpretation of pictorial content develops before accurate size estimation. This is the reverse of Jahoda and McGurk's (1974) Scottish subjects responding to both the coloured version of the test and the black-and-white version of the test (Jahoda and McGurk 1975), although the difference in the latter case is less marked. In their cross-cultural study using the coloured test (Jahoda and McGurk 1974b), the Hong Kong boat children and the older (ages 8 and 9 years) urban Hong Kong children had more accurate spatial scores than size scores. A possible reason for inaccurate size estimation is that Malawian subjects might not have learned to ignore cues for the flatness of the picture plane and that such cues are more salient for size estimation than for spatial interpretation. This possibility is explored in Chapter Six.
CHAPTER SIX

Introduction

In viewing a picture, the observer receives conflicting information from the cues for depth in the static pictorial presentation and the cues for flatness of the surface on which the picture is drawn. Young children must learn to ignore the cues for flatness before being able to interpret the picture as a 3-dimensional scene.

Yonas and Hagen (1973) varied the information for dimensionality of a scene by using 3-dimensional displays and 2-dimensional projections of those displays and by varying head movement, thereby manipulating motion parallax. As they pointed out, with a 2-dimensional display, motion parallax provides information for the common distance of all forms in a scene, because all the points on the picture plane translate across the retina at an identical rate. If motion parallax is eliminated, this information for flatness is removed. Four conditions were created in their experiment, with increasing availability of information for flatness: a 3-dimensional motion parallax present condition, a 3-dimensional motion parallax absent condition, a 2-dimensional motion parallax absent condition, and a 2-dimensional motion parallax present condition.

In order to assess sensitivity to depth, the subject viewed two objects, or pictures of objects, located at
different distances and was asked to indicate the larger of the two. In the 3-dimensional motion parallax present condition, the S viewed the objects monocularly through a slit, so that head movement information was available. In the 3-dimensional motion parallax absent condition, viewing was through a small hole, and only static cues to depth were therefore available. In the 2-dimensional conditions, Ss viewed slides of the 3-dimensional displays monocularly, with or without head movement. Conflicting information for depth is greatest in the 2-dimensional motion parallax present condition because there is both static and kinetic information for the picture plane. The subjects tested were 3 and 4 year olds, 7 and 8 year olds and adult Americans. Yonas and Hagen found a greater difference in performance of children between the 2-dimensional motion parallax present and the 3-dimensional motion absent conditions, than between performance of adults in the same two conditions. They attributed this difference to the adults having acquired a strategy of ignoring the information for the picture plane.

The Yonas and Hagen experiment was replicated on Malawian subjects from the same age groups in order to assess whether the strategy of ignoring the information for the picture plane also develops in Malawians. If this strategy does not develop as early, it would explain the depression of size scores found in the previous experiments. The independence of size and spatial accuracy exhibited by Malawians in experiments 4-8 is consistent with the
empirical evidence presented in Chapter Three indicating that estimations of size and distance in photographs are made independently. It appears that, in order for size to be accurately scaled in a photograph, it must be recognised that the photograph represents a three-dimensional scene. In order for such recognition to occur, information for the 2-dimensionality of the picture plane must be ignored and information for 3-dimensionality attended to. The absence of such a strategy would be expected to reduce the accuracy of size judgements and help to explain the rather low size scores found in the previous experiments. By making comparisons of size judgements of three-dimensional displays both with and without head movement, it is also possible to assess whether kinetic information is necessary for accurate size judgements.

**Subjects**

There were 120 subjects, 40 in each of three age groups: 3 and 4 year olds from the University Nursery School, the Zomba Town Council Play Group and the Zomba Play Group; 7 and 8 year olds from Mponda Primary School in Zomba; and students taking first year Biology at Chancellor College. Within each age group, Ss were matched as far as possible for sex and randomly assigned to each of the four conditions.
Apparatus

An alley was constructed of hardboard, 1.83m long by .76m wide by 0.61m high. It was made in two sections, each 0.91m long and 0.76m wide and with hinged walls so that it folded almost flat for transportation. The two end sections were bolted into place and the two halves then hooked together for use. The inside of the alley was painted flat white and was randomly textured with black splotches using a paper towel dipped in flat black paint. At one end of the alley a slit 5.1cm by 15.2cm was cut out of the hardboard, the centre of the slit being 15.2cm from the floor of the alley, and a hole 1.6mm in diameter was made in the centre of the 5.1 x 15.2cm piece of hardboard extracted from the slit. For the motion parallax absent condition, the 5.1 x 15.2cm piece of hardboard was repositioned and it was covered (except for the hole) with a piece of white card to ensure that the display was not visible through any gaps, but only through the small hole.

Three squares and three equilateral triangles were used for relative size judgements. The objects were all cut out from 5.1cm thick wood and were 16.5cm, 21.6cm and 25.1cm on a side. All were painted flat black. The displays used in the 3-dimensional condition were photographed from S's station point and slides of the displays were back projected onto a sheet of tracing paper which fitted between the two sections of the alley and was therefore 91.4cm from the subject's eye. A Kodak Carousel slide projector was placed
so that the retinal images of the objects projected on the screen matched those projected from the actual objects.

**Stimuli**

In the three-dimensional condition, the test stimuli consisted of 16 displays that were viewed directly, and in the two-dimensional condition 16 transparencies of these displays were projected. There was also a set of training displays for each of the two conditions. The training displays for the 3-dimensional condition consisted of 8 displays in which two objects (two triangles or two squares) were placed on the floor of the alley 94cm from S's station point, and 8 displays in which the larger object was placed at 91.4cm and the smaller one at 120.7cm from S's station point. The 16.5cm object was paired with the 21.6cm object in half the displays and with the 25.1cm object in the other half. The larger object was on the right in half the trials and on the left in the other half. Because of difficulties with processing, only 9 of the training photographs were suitable for use, but this in practice proved to be sufficient.

The test displays differed from the training displays in that the larger object was positioned so as to subtend a visual angle equal to or smaller than that subtended by the smaller object; this was done by placing the 16.5cm object at 91.4cm and either the 21.6 inch object at 120.7cm or the 25.1cm object at 1.42m. In 4 of the remaining 8 test
Figure 15. Examples of arrangements of objects in experiment 9.

100% visual angle arrangement.

100% visual angle arrangement.

80% visual angle arrangement.

70% visual angle arrangement.
trials, the larger object was positioned so as to subtend 80% of the visual angle of the small object at 91.4 cm, and this was achieved by placing the 25.1 cm object at 1.68 m. In the remaining 4 test trials, the 21.6 cm object was placed at 1.68 m, and it then subtended a visual angle of 70% of the small object at 91.4 cm. There were thus 8 test trials in which the visual angles subtended by the two objects were equal, another four in which the visual angle subtended by the larger object was 80% that subtended by the smaller object and four in which the visual angle subtended by the larger object was 70% that subtended by the smaller object. Examples of the photographs are shown in figure 15.

Procedure

Subjects were set at ease and told that they would be asked to look at some things and to show which was the big one. They were seated at the end of the viewing box, and those in the motion parallax present conditions had an eyepatch fitted so as to ensure monocular viewing. Motion parallax was restricted when viewing through the small hole and made possible when viewing through the slit. The subject was then asked to look inside the box at the first training display, and to say which of the things was the big one. Children were asked to indicate with their hands, but adults responded verbally if they so wished. Throughout training, the objects were either equally distant from S, or the larger object was nearer than the smaller one.
responding, Ss were either told they were correct or were corrected and asked to look again carefully if they were wrong. Training was continued to a criterion of five consecutive correct responses. Upon reaching criterion, the subject was told that (s)he had done very well and that (s)he would no longer be told of the correctness of his(her) response, but that (s)he must go on looking carefully at the objects and indicating the big one. If a subject said that the two objects were the same size during testing, (s)he was asked to guess which was the larger.

Testing was carried out by the author and a male teaching assistant from Chancellor College. The adults were tested in English and the children in their vernacular language.

Results

The number of trials on which the physically larger object was chosen was counted and transformed into mean percentages correct. These data are presented in Table 6.1.
Table 6.1

Mean percentages correct choices of the physically larger object for four conditions and three age groups.

<table>
<thead>
<tr>
<th></th>
<th>3 and 4 years</th>
<th>7 and 8 years</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% 80% 70%</td>
<td>100% 80% 70%</td>
<td>100% 80% 70%</td>
</tr>
<tr>
<td>2D MP</td>
<td>65 15 10</td>
<td>78.8 17.5 12.5</td>
<td>95 67.5 32.5</td>
</tr>
<tr>
<td>2D</td>
<td>75 45 27.5</td>
<td>82.5 32.5 20</td>
<td>96 75 32.5</td>
</tr>
<tr>
<td>3D</td>
<td>72.5 52.5 12.5</td>
<td>95 72.5 17.5</td>
<td>99 88 15</td>
</tr>
<tr>
<td>3D MP</td>
<td>91.3 81.3 65</td>
<td>95 97.5 96</td>
<td>96 95 98</td>
</tr>
</tbody>
</table>

Since the response measurements for analysis are proportions, the assumptions of an analysis of variance, namely normality and homogeneity of error variance, are not strictly satisfied. However, the ANOVA technique is quite robust against departures from normality and two preliminary analyses of variance were computed, one using the raw proportions and the second using a variance stabilizing arcsine transformation of the data. Such a transformation is also likely to normalize the data.

Subjects falling within each age, motion parallax and dimension treatment condition were tested at each of three angles. Table 6.2 shows the 4-way analysis for the transformed data with angle as a split-plot variable. The interpretations which are given below from this table are consistent with those from a similar table using the untransformed data, and are also quite evident from Table 6.1.
There were five significant 2-way interactions. (1) The interaction between dimension and motion parallax was highly significant (F=38.39, df=1,108 p<0.001) and resulted from a tendency for motion parallax to improve judgements of 3-dimensional displays but to reduce the accuracy of judgements of photographs. (2) The interaction between dimension and age was less marked (F=3.41, df=2,108 p<0.05) and resulted from children performing relatively less well than adults in response to 2-dimensional displays. (3) The interaction between motion parallax and angle (F=21.39, df=2,216, p<0.001) was due to a relatively greater improvement from the 70% visual angle arrangement through the 100% arrangement when there was no motion parallax than when motion parallax was allowed; this in turn resulted from the low scores of adults as well as children with the 70% arrangement in the 3-dimensional motion parallax absent condition. (4) The interaction between dimension and angle was less marked (F=16.50, df=2,216, p<0.05) and resulted from a greater increase in scores with the 2-dimensional than with the 3-dimensional displays with increase in the angle subtended by the more distant object. (5) Finally, there was an interaction between angle and age (F=2.74, df=4,108, p<0.05), which was due to the adults' rather surprisingly low scores for the 70% visual angle arrangement under the 3-dimensional motion parallax absent condition.

There were also highly significant main effects for age (F=16.45, df=2,108, p<0.001), dimension (F=56.44, df=1,108,
p<0.001), and motion parallax \((F=10.12, \text{df}=1,108, p<0.001)\), but these must be considered carefully in the light of the interactions.

Duncan Multiple Range tests \((p<0.05)\) showed that (1) there were significant differences between the means for the adults and the children but that the differences between the two groups of children just failed to reach significance, and that (2) there were significant differences between the means of each of the visual angles.

Two interactions were then considered in more detail, and although the above results of preliminary tests seem very well founded, subsequent tests were performed using non-parametric techniques, thus allaying any concern about non-normality.

The dimension x motion parallax interaction was investigated by looking at each age level and each visual angle arrangement. Wilcoxon rank sum tests were used to compare judgements made under the motion parallax present conditions with those made under the motion parallax absent conditions. Judgements made with the 3-dimensional displays will be considered first. The addition of motion parallax significantly improved scores under all three visual angles for the youngest group \((W<78, p<0.05, 1\text{-tailed})\) and under the 70% \((W=56.5)\) and 80% \((W=61.0)\) visual angles for the 7 and 8 year olds, but only under the 70% \((W=55.5)\) visual angle for adults. The effect of motion parallax thus reduces with age when judgements of 3-dimensional displays
are being made. Turning to judgements made with the 2-dimensional displays, it was found that motion parallax does not control subjects' responses to the same degree. A comparison of scores for the motion parallax present and absent conditions revealed no significant differences except for the youngest group with the 80% visual angle (W=82, p<0.05, 1-tailed). However, it should be noted that percentages of correct choices to photographs were consistently lower when motion parallax was allowed than when it was not.

The interaction between age and dimension was also considered in more detail. Wilcoxon tests were computed at each age level and for each visual angle. For children, 3-dimensional scores were significantly higher than 2-dimensional scores (W.138, p<0.05, 1-tailed) for all visual angle arrangements. For adults, there was no significant difference with the 100% visual angle arrangement (W=189, p<0.05, 1-tailed) but significant differences with the 80% (W=126.5) and 70% (W=137) visual angle arrangements.

The main effects of the analysis, which were for age, dimension and motion parallax, can now be considered. The effect for dimension is clear, with 3-dimensional scores, not surprisingly, being better than 2-dimensional scores. The effect of motion parallax has already been considered in terms of its interaction with dimension. The effect of age shows up in the higher means for adults as compared with the
two groups of children, indicated by the multiple range test reported above, and has been considered in terms of its interaction with dimension and angle.

Although percentages of correct choices were lower for the 2-dimensional displays when motion parallax was allowed than when it was not, the differences between the two conditions was not significant in any age group ($z<1.64$ by Mann Whitney U test). Motion parallax did not therefore by itself control choices made in response to photographs. Likewise, there were also no significant differences between percentages of correct choices under the 2-dimensional and 3-dimensional conditions without motion parallax, indicating that the addition of information for the picture plane did not by itself reduce the percentage of correct choices.

The hypothesis that addition of information for the picture plane depresses children's scores to a greater extent than those of adults was tested. Judgements made under the 3-dimensional motion parallax absent condition were compared with judgements made under the 2-dimensional motion parallax present condition for each visual angle arrangement in turn. Children's scores were significantly depressed by addition of information for the 2-dimensionality of the picture under all three visual angles ($U\neq 83$, $p<0.05$, 1-tailed test) but adults' scores were only depressed under the 70% visual angle arrangement ($p<0.05$). The hypothesis receives support from this analysis and it can be concluded that information for the
picture plane reduces the accuracy of children's size judgements to a greater extent than those of adults.

Discussion

When the results presented here for Malawian subjects are compared with those obtained for American subjects by Yonas and Hagen (see Appendix D), it is seen that the percentage of correct responses made by the American subjects is higher than that made by Malawians, albeit in some cases only marginally. Such a difference could be a result of a true difference between samples, or it could be an indication of greater difficulty faced by Malawians in this testing situation. Yonas and Hagen make no reference to any testing problems, and one therefore assumes that they had none. Testing the Malawian 3 and 4 year olds was at times problematic; some of the children appeared to be unable to orientate themselves in relation to the display and tried to point into the box in the motion parallax absent conditions. Some children were frightened by the eyepatch. However, by the end of training, they adjusted to the demands of the situation, and any child who was too frightened or unresponsive was not tested. The fact that 7 and 8 year olds and adults performed on a level comparable with the Americans for the 3D motion parallax present condition, taken together with the care used in training, suggest that the results can be considered as a true reflection of the subjects' ability to judge size under
these conditions.

The results support the hypothesis that conflicting information for the picture plane reduces the tendency for children to perceive depth in the pictures. Children gave fewer correct responses in the 2-dimensional motion parallax absent condition than in the 3-dimensional motion parallax absent condition. Their accuracy was also reduced to a greater extent than adults' by the addition of information for the two-dimensionality of the picture. Adults appear to have learned the strategy of ignoring the information for the picture plane, however, the strategy breaks down when the static depth information is weak, as in the 70% viewing arrangement.

Motion parallax information controls children's responses in the 3-dimensional condition, and the percentage of correct responses in the 3-dimensional motion parallax absent condition was significantly lower than the percentage correct in the 3-dimensional motion parallax present condition under all visual angles for the 3 and 4 year olds and under the 70% and 80% visual angles for the 7 and 8 year olds. Adults' scores were significantly lower under the 70% visual angle only. Adults appear to be utilising static depth information under the 80% and 100% visual angles.

The adult Malawians have a much lower percentage of correct responses than the American adults under the 70% visual angle for all conditions except the 3D motion parallax present condition. These results for the Malawian
adults are more similar to the American 7 and 8 year olds than to the American adults. This suggests that the Malawian adults have learned the strategy of ignoring the information for the picture plane, but have not learned to fully utilise the static information for depth in the picture. Thus when the static information for depth is weak, the information for the picture plane controls responses. The present experiment illustrates nicely how the information for depth may become insufficient to control responses as the angle subtended by the more distant object becomes increasingly smaller than the angle subtended by the nearer object.
CHAPTER SEVEN

Summary of results

The results of experiments 1-3 support other research in finding that modifications of the Hudson test can induce greater perception of pictorial depth than the original (Omari and MacGintie 1974, Hagen and Johnson 1977). A significantly greater proportion of subjects in experiments 1-3 were able to identify the items in the modified pictures, and a greater proportion of subjects gave the three-dimensional response to the modified version of Hudson's picture (Card 2) than to Hudson's original (Card 1). From age 9-10 years, at least 60% of all age groups of subjects tested (see Table 4.4) gave three-dimensional responses to each of the modified pictures, (with the exception of the 9-10 year olds who were 50% three-dimensional on card 2), and this percentage is higher than that reported by researchers using the Hudson test, especially for the unschooled. For example, none of the illiterate mine workers in Hudson's (1960) study gave the three-dimensional response to card 1, and only 13% of the illiterate white labourers did so. However, of Hudson's two samples of black Primary school children (aged 14-20 years), 50% of the Standard 6 children and 69% of those in Standards 8 and 10 gave the three-dimensional response to card 1.
Young Malawians gave significantly fewer three-dimensional responses to the Hudson picture than to the modified version at all ages. Over 60% of all subjects aged 14-20 years gave the three-dimensional response to the modified picture (Card 2) in the present study; as this figure is for schoolchildren combined with unschooled, and the unschooled were less three-dimensional than the schooled, it is an underestimation of the value for the schoolchildren. Mundy-Castle (1966) found only one consistent three-dimensional perceiver in his sample of 122 Ghanaian Primary school children. The modified stance version of the 'boy' pictures in the present study elicited 100% three-dimensional responses from adults, and high percentages correct for the two younger groups of subjects.

Identification of the items in the 'boy' pictures was more accurate than identification of the items in the Hudson picture (card 1). It was argued that the items in the former were more familiar to subjects than were items in the latter. Although correct identification does not imply perception of pictorial depth, incorrect identification could hinder it by rendering unavailable the cue of familiar size.

Age and education were both associated with greater perception of pictorial depth, and there were indications that a plateau was reached by the unschooled during the teenage years. It was also shown that an association existed between parental education and the schoolchildren's
perception of pictorial depth, and the confounding of the educational status of the subject with other factors associated with the educational level of the parents was discussed. It cannot be concluded that the school is responsible for the insculcation of pictorial skills, because the chance of the child attending school varies with the socio-economic level of the family. However, the association is perhaps less marked than might be expected from Western social norms because, although the family pays school fees for both Primary and Secondary education, it must be understood here that the term 'family' means the extended rather than the nuclear family. A child's nuclear family might be very poor, but (s)he might have been able to go to school because a wealthier relative paid the school fees. There was a second confounding factor, in that the schoolchildren lived in or relatively near a small town, whereas the unschooled were living in the traditional rural village. Once again, however, the influence of the town might not have been very great, in that it did not provide much in the way of amenities. The concepts of family, education and urban environment are of necessity broad, and cover many variables that might be specifically associated with perception of pictorial depth. However, one important factor is thought to be an exposure to a wider variety of views of the environment, including pictorial materials, and a second is a tendency to analyse visual experiences which would arise from learning to read and write.
The size scores obtained from the huts pictures in experiments 4 and 5 indicated that subjects were operating for the most part at chance level from ages 4-5 to 13-14 years (see Tables 5.1 and 5.3). The nursery school children's scores were higher than all other groups, albeit marginally. Educated adults' scores were substantially higher than 13-14 year olds', indicating that there was an effect due to age and education, but because the series of pictures was difficult the effect was not evident until late teenage. There was also an increase in correct spatial responding with age (see Table 5.2) for both the schooled and unschooled children. The schoolchildren displayed greater spatial accuracy even at age 4-5 years, while the scores for the University students were maximum. The curve for the unschooled started lower, but scores were increasing through the oldest age group tested, 13-14 years.

Depth cues elicited only limited differential responding. In experiments 1 and 2 it was shown that there was a tendency for the cue of interposition to elicit more 3-dimensional responses than the cue of linear perspective in both versions of the 'boy' pictures. There was little difference between the proportion of 3-dimensional responses given to the drawing with the cues of familiar size and elevation (card 2) and to the drawing with the additional cue of linear perspective (card 4). In contrast to present findings, neither Hudson (1960) nor Deregowski and Byth (1970) found that the cue of interposition was effective in
eliciting three-dimensional responses. Deregowski and Byth speculated that this might have been because the interposition cues were too weak, there being no overlap of the elephant (a target figure) by the hunter or antelope. The power of interposition as a cue to depth in the present study might well have resulted from the overlapping of one target object by another, whereas in Hudson's pictures there is no overlapping of the elephant by either the man or the antelope, instead the cue is given by the overlapping of landscape lines.

No differential responding was found to the cues of linear perspective, texture gradient or aerial perspective with the 'huts' modification of the Jahoda-McGurk test. This is consistent with the results obtained for McGurk and Jahoda's (1975) Ghanaian samples. It is not easy to give an impression of aerial perspective in a black-and-white drawing, but it was thought that a reasonable effect had been produced by shading the rearground hut and the horizon line with white chalk. However, some of the Primary school children, when asked for comments at the end of the testing session, revealed that they had not picked up the information as a cue to depth, and tended to interpret the hazy effect in the rearground as a printing defect. There was a slight tendency running through the results presented in Chapter Five for the addition of the cue of texture gradient to elicit more correct size responses than the addition of either linear perspective or of elevation alone.
Further evidence of the significance of pictorial content was given in experiments 4, 7 and 8. In particular, the comparison of scores obtained by the 13-14 year olds responding to the 'huts' and 'figures' series of drawings and the 'tins' photographs, showed an overall significant difference, with scores on 'huts' being lowest and scores on 'tins' being highest. In all three series the horizon line was situated in such a position as to give little or no size information - in the huts pictures the horizon was above the huts, in the figures pictures it undulated, and the top of the rearground adult's head just superimposed it when in the right hand position; the photographs had no horizon. The photographs provided additional depth information from texture and shadow but texture has not been shown to be a powerful cue in these experiments. The results thus lead to the conclusion that the photograph was most frequently interpreted three-dimensionally because it conveyed more information corresponding to that from the real scene than either of the drawings; in addition to texture and elevation, there were shadows cast by the tins, and the shape of the tops of the tins suggested their three-dimensionality.

The results of the manipulation of information for the picture plane in experiment 9 again showed an effect of age on accuracy of relative size estimation. There was an interaction of age with dimension and of dimension with motion parallax. Children performed relatively less well
than adults in response to the pictorial displays, and the addition of motion parallax enhanced the accuracy of children's judgements of the size of objects in a three-dimensional display, but tended to decrease the accuracy of judgements made of objects in photographic slides. These results are in accordance with the findings of Yonas and Hagen (1973).

Removal of motion parallax information significantly reduced children's accuracy of size judgement of objects in a three-dimensional layout. Adults' accuracy of size judgement was not reduced when the visual angle subtended by the larger (and more distant) object was 100% or 80% the visual angle subtended by the smaller object. Children thus relied more heavily than adults on kinetic information in making size judgements in a three-dimensional display.

The effect of conflicting information for the picture plane was greater in children than in adults who thus appear to have learned a strategy of ignoring the information for the picture plane. However, there were indications that the strategy breaks down when the information for depth from the relative size of the objects becomes weaker.

In summary, findings from this series of experiments have demonstrated that young Malawians are sensitive to pictorial information for depth in that the majority of them gave the three-dimensional response to the question 'Which hut is nearer...?' in experiments 1 and 2, and that they were able to make increasingly accurate size judgments with
age in experiments 5-8. Pictorial familiarity enhanced depth perception, but there was little sensitivity to individual depth cues. Both schooling and an educated home environment were associated with greater accuracy of distance judgements in experiment 1. In general, young Malawians displayed less accuracy of size judgements in experiments 5 to 9 than European children and adults tested herein and in previous research using the same or very similar testing techniques.

Discussion

a. Contrast of the Hudson method with the Jahoda-McGurk method

The Hudson test was criticised on several grounds. The pictorial content has been discussed at length, but another area of criticism which has not been closely examined is the nature of the verbal testing procedure. Mundy-Castle (1966) gave the longest version of the Hudson questions, and they were used here in experiment 1. Mundy-Castle reports that he repeated the full set of questions for each card, and although there were only four cards in his set, the repetitions became irksome. In the present test, the identification questions were only repeated when a new item was introduced in a picture, and this made for a more lively procedure. An even more satisfactory procedure from the
point of view of maintaining good rapport was that used when
the stance of the boy was corrected. In this case, the
'story' of the picture was explained and the only question
to be answered, apart from the identification question was
'Which hut is nearer the boy?'

The Jahoda-McGurk modifications used in the present
research surprisingly appeared to pose problems for the
Malawian subjects. Their spatial scores were accurate as
compared with those reported by Jahoda and McGurk (1974a and
b, McGurk and Jahoda 1975), but their size scores were
rather less accurate than expected. Pictorial explanations
were sought for this discrepancy, and pictorial alterations
were found to bring about significant increases in accuracy
of size responses. One such increase was found in the size
scores to the photographs of the Lactogen tins as compared
with the figures drawings and in these as compared with the
huts drawings. In this case, pictorial depth perception was
influenced by pictorial content rather than layout or depth
cues per se.

During testing, especially with the 'huts' pictures,
subjects demonstrated an apparent ability to perceive one
hut as farther away than another, in that they positioned
one model farther away on the response board, but they
appeared to experience some difficulty recalling whether the
hut drawn on the paper was the living hut or the dormitory.
Some subjects took a few minutes deciding which hut was
drawn in the foreground before transferring their attention
to the rear ground hut (or vice versa), and this gave the impression that they were attempting to recall the drawn size. This behaviour suggested that they were experiencing problems of memory such as demonstrated by McGurk and Jahoda (1974). They found increased size accuracy when one of the training pictures was left in view while subjects performed the test, but the increase was fairly small.

Leach (1977a) argued that the variations of Hudson’s test devised by Page (1970), Omari and Cook (1972) and Opolot (1976) as well as the Jahoda-McGurk test imposed a perceptual task different from that of Hudson. In the former tasks, the subject has to estimate only two portrayed distances, from himself to each of the animals, and this implies an ability to interpret depth cues. Leach calls this pictorial depth interpretation (p.d.i.). In his view, the Jahoda-McGurk size scores measure p.d.i.; as does Leach’s own question ‘As you look at the picture, who is near to you...?’ Page’s version, which replaced ‘the man’ with ‘you’ in the question ‘Which is nearer the man, the antelope or the elephant?’ and the alternatives of Omari and Cook and Opolot (Which looks/is nearer/farther to you/the man...?’) also require only p.d.i. Opolot ascribed to children’s egocentrism his finding that even at Grade 1 level, the question form incorporating ‘you’ elicited significantly more responses implying pictorial depth than the question form incorporating ‘the man’. Leach disagrees and claims instead that Hudson’s question (Which is nearer
to the man...?) imposes a problem of a different order to the above, and "requires an estimation of at least five, and possibly six, portrayed distances, viz. the three distances between himself-as-viewer and each of the elements of the picture (man, antelope, elephant), and then at least two of the three distances between the elements themselves, these last distance estimations being directly dependent upon the first three" (1977, p. 52). This taps, not the subject's perception of depth, but his understanding of the spatial relationships, and Leach calls this pictorial space comprehension (p.s.c.). Leach's assertion that the observer must calculate 'at least five... portrayed distances' is questionable, for the subject is being asked to make an estimation of the relative, not the absolute distances between each of the two animals and the man. It is not necessary to know the distance of each animal from the observer in order to do this, for the distance from the observer to the surface of the picture is a constant which can be taken into account. The task may still be more difficult than that of judging the relative distances from the observer, but not necessarily because of the number of distances to be estimated.

According to Leach, p.s.c. implies p.d.i., the latter being achieved prior to the former. He cites Jahoda and McGurk's (1974b) developmental study in Scotland as evidence in support of his own findings. The size judgements in the Jahoda-McGurk test require only p.d.i., whereas the spatial
judgements require p.s.c., and the authors found higher size scores than spatial scores in the younger subjects. Whether or not the scores can be considered as part of the same scale is questionable, but not central to the present argument, and will not be considered farther. What is relevant is the results presented here in Chapter Five which showed higher spatial scores than size scores, and thus provide evidence conflicting with that from the Jahoda-McGurk experiments and with the Leach predictions. It must also be noted that not all of Jahoda and McGurk's samples displayed greater size than spatial accuracy; in their cross-cultural study using the coloured test (Jahoda and McGurk 1974a), the Hong Kong boat children had more accurate spatial than size scores.

This puts into question the notion of a developmental sequence with p.d.i. being achieved prior to p.s.c., and lends further support to the independence of size and spatial judgements. In addition, there is evidence from the spatial scores in the present experiments that spatial accuracy varies with the relative elevation of the two objects. Thus there was greater vertical separation of the two huts than of the two figures or two tins, with no vertical overlap of the rearground hut by the foreground hut, whereas there was vertical overlap of the rearground figure and tin by the foreground figure and tin respectively. Spatial scores were most accurate with the huts pictures, but size scores were least accurate.
Elevation thus appears to provide primarily spatial information. McGurk and Jahoda's older subjects (13 year old Ghanaians and 10 year old Scottish from the 1975 report and 8 year old and 10 year old Scottish from the 1974 report) exhibited higher spatial than size scores, and the present results for the figures task are very similar to those for their Ghanaian sample. The age at which spatial scores become greater than size scores varies with pictorial cues other than elevation which tend to increase the accuracy of size scores (McGurk and Jahoda 1974 and 1975). The pattern that emerges from Jahoda and McGurk's research and the present study is of a sharp increase in spatial accuracy with age, and a rather slower increase in size accuracy with age. The age at which the crossover occurs varies with pictorial content, and with samples. The increase in size accuracy with age is small relative to the differences between cultural groups, which will be considered again in section g.

Leach also questioned the assertion that non-verbal tests are more satisfactory than verbal tests in the African context. He suggested that the unusual nature of the task from the subject's point of view might have suppressed scores, and oral tasks might be more appropriate to some African cultural groups. The evidence from the rather low scores obtained in Chapter Five tend to lead to agreement on this point, and towards the conclusion that it was not the verbal questioning per se of the Hudson test which
presented difficulties, but the content of the questions.

b. Spatial development

When subjects selected models and placed them on the response board in experiments 4 through 8, they positioned the models in one of two ways. The younger subjects tended to align the models horizontally, whereas the older subjects aligned the models diagonally. The schoolchildren displayed greater spatial accuracy than the unschooled and both the Malawian University students and the European 7-8 year olds achieved virtually maximum spatial scores. There was no difference in spatial scores with different depth cues and no evidence of a reduction in spatial scores with the addition of the cue of linear perspective as found cross-culturally by Jahoda and McGurk (1974a and b) with coloured pictures. However, the lack of any influence of the cue of linear perspective on spatial scores is consistent with McGurk and Jahoda's (1975) Ghanaian sample whose spatial scores were not reduced by the addition of the cue.

Jahoda and McGurk (1974b) consider two interpretations of their data. First they discuss the possibility that subjects mentally laid the picture on its back in order to perform the spatial positioning of the models of the response board. It will be recalled that the pictures were displayed vertically to the subject, and his arrangement of
doll's was made on a horizontal response board. If the subject imagined the picture lying on the table, he could then copy the relative positions of the figures onto his response board. The authors rejected this interpretation because their subjects' size scores were higher than their spatial scores, indicating an interpretation by the subjects of pictorial depth; and they turned to their second, and favoured, interpretation in terms of frames of reference. This interpretive scheme will be considered first, and then, because some data presented herein conflicts with the scheme, their first interpretation will be reconsidered.

The authors interpreted their results in terms of a developmental sequence analogous to the stages outlined by Piaget and Inhelder (1956) to account for the child's construction of the projective line. "Rate of development is regarded as a function of the extent to which alignment of response figures is influenced by the presence of various frames of reference within the two-dimensional array, rather than as a function of the ability to discriminate pictorial depth per se". Size scores, rather than spatial scores, are considered to be indicative of pictorial depth perception. They go on to propose that during the first stage of development, subjects use the contour of the picture as their frame of reference and thus align their models with the bottom horizontal boundary. During the second stage, subjects begin to employ the internal structure of the picture as the frame of reference, providing that there are
few other frames in competition. Finally, subjects become free of all frames other than that provided by the internal structure of the picture. This interpretation is consistent with Jahoda and McGurk's own findings of increased spatial accuracy with age, and of reduced spatial accuracy with the addition of linear perspective in the form of the path and the fence in their colour pictures.

The results of the present research and of McGurk and Jahoda (1975) appear to conflict with this interpretation, because the linear perspective cue did not interfere with spatial accuracy. McGurk and Jahoda (1975) speculate that Ghanaian children omit the postulated second stage of development. It is also, however, possible that the linear perspective cue in the black-and-white drawings was not powerful enough to disrupt the utilisation of the internal structure of the picture as a frame of reference; the path is portrayed by two converging lines whereas in the coloured version it is portrayed as a band of different colour from the background converging in the distance.

It was suggested (Chapter Five) that the Jahoda-McGurk test taps two different abilities and that while the size scores are indicative of the ability to judge relative size at a distance and thus indicate perception of depth, the spatial scores reflect a spatial ability of the type needed for the construction of a diagonal (Olson 1970). Positionning of only two objects at the ends of the diagonal in the picture perception test is less demanding than the
construction of the diagonal line joining them, and subjects all demonstrated their ability to diagonally align the models prior to testing. It has been shown that the scores on a task similar to Olson's are correlated with spatial scores on the Jahoda-McGurk test, but not with size scores (Bond, 1979). An observer can in fact interpret the picture two-dimensionally and still achieve perfect spatial scores. The correct spatial positioning of the models requires a translation from the vertical picture to the horizontal response board, and the subject has to remember only one correspondence (and its converse), that higher up (in the vertical picture) corresponds to farther away (on the horizontal board).

The interpretation of data that the authors considered first and rejected was that subjects approached the task by imagining the test picture laid on its back, but they claim that this would have led to more accurate spatial responding than size responding. As the results reported in that study showed subjects to have more accurate size responses than spatial responses, they rejected this explanation. In fact, as mentioned above, in their cross-cultural replications with the colour pictures, one sample of children (the Hong Kong boat children) had spatial responses which were more accurate than their size responses, and in their subsequent study with the black-and-white pictures, Ghanaian children's spatial scores were also more accurate than their size scores. Imagining the picture laid on its back can not
therefore be rejected as an explanation for spatial performance for the reasons suggested by the authors. McGurk and Jahoda (1974) demonstrated that the problem for young children lies in the selection and positioning of the models rather than in the perception of their relative positions, and that this is disrupted by pictorial frames of reference. The present findings suggest that the competing frame must be strongly portrayed in order to disrupt alignment with the horizontal boundary of the picture.

Spatial ability as indicated by the construction of the diagonal, as in Olson's study, might be influenced by spatial experience in everyday life. Munroe and Munroe tested Kenyan (Logoli and Kipsigis) children, some of whom had no schooling and some of whom had 1-4 years of schooling, with Olson's task (Olson 1970). The Kenyan children experienced great difficulty in copying the diagonal, and success was strongly related to schooling. The problem did not lie in the testing medium, for virtually all the children could copy the top row of a checkerboard display. Munroe and Munroe reported that most Logoli children were unable to read after two years of schooling, and in their opinion, the schoolchildren's success was not related to literacy. They noticed that Logoli boys had more success than the girls in copying the diagonal and attributed this sex difference to the boys' greater motor and spatial experience - the girls tended to stay close to home and be involved in tasks, whereas the boys were more
free to wander and explore.

g. The relative efficacy of pictorial depth cues.

The general finding of this research is that static, or pictorial, cues to depth had little differential influence on perception of size by Malawians at each age level. Only interposition emerged as significantly enhancing three-dimensional responses on its own. The relative efficacy of object size, texture gradient, aerial perspective, interposition, linear perspective and elevation have been considered at a number of points in this research. Elevation covaries with object size in a perspective drawing, and McGurk and Jahoda (1974) showed elevation alone to be a relatively weak but effective cue to depth. However, it was suggested above (section b) that elevation was primarily a spatial cue for young Malawians. The present findings are that the effectiveness of elevation is dependent on the pictorial content; thus in the hut series of pictures no cues were effective, while in the figure series elevation alone was a weak depth cue. There was evidence that the aerial perspective effect was not interpreted as a cue to depth. Elevation with texture gradient elicited marginally more accurate size responses than elevation alone in the majority of samples, whereas there were no indications of increased accuracy of size scores with the addition of linear perspective. The fact that the road was indicated by only two lines in each
drawing might have contributed to the ineffectiveness of linear perspective as a cue.

The role of the horizon line remains unclear. Young subjects doing the original Hudson test and Silliman's version of it (Silliman 1979), misidentified the horizon, calling it a 'road' or a 'stick'. Silliman's subjects were Americans in elementary school and they were accurate in identifying the hill. Mundy-Castle's (1966) Ghanaian subjects almost without exception misidentified the horizon.

The horizon line in Hudson's pictures with linear perspective is a straight line, and this might have contributed to its misidentification, for it is unusual to see such a horizon except in projection of a large expanse of water. When it is correctly identified, the horizon can play an important role in establishing the scale of a picture and depth relations within it. In view of the ineffectiveness of the other static cues to depth for Malawians, it is possible that horizon ratio information would be equally ineffective. An experiment was designed to test for a responsiveness to horizon information (see Appendix C) but it was not possible to run it. The pictures used in experiments 1 and 2, along with the series of pictures used in experiments 4-8, with two huts, two figures and two Lactogen tins were all designed to circumvent the problem of the horizon. Thus in the latter, there was no horizon line, while in the former, the horizon line did not intersect the items in the drawing. This might have
contributed to lower scores than anticipated throughout the
Chapter Five experiments. Size scores were generally lower
than those obtained by Jahoda and McGurk for Ghanaian
subjects, and although changing the pictures from huts to
figures to photographs did significantly raise size scores,
it did not raise them to the expected level. As discussed
previously, the Jahoda-McGurk pictures displayed a greater
proportion of the rearground adult than of the foreground
adult above the horizon line, predisposing subjects to
identify the rearground figure as an adult even when its
pictorial size was smaller than that of the foreground adult
thus enhancing the accuracy of size scores. If this
interpretation is correct, then it must be questioned why
subjects were so frequently correct in responding to the
modified version of the Hudson pictures in which, again, the
horizon line had been raised in order to prevent confusion.
A plausible, but post hoc, explanation lies in the
proportion of the rearground hut to the foreground hut: in
the 'huts' pictures, the dimensions of the rearground hut
were two-thirds the dimensions of the foreground hut whereas
in the modification of the Hudson pictures, the rearground
hut was less than half the size of the foreground hut. The
relatively smaller rearground hut suggests greater distance.
Perhaps even more important, the judgements made of the
'boy' pictures were distance judgements whereas those to the
modified versions of the Jahoda-McGurk test were size
judgements. The horizon line deserves more attention, and
and it would be interesting to know at what stage Malawians utilise horizon information. Very little work has been done on it even in Western subjects. Sedgwick (1973) did find evidence of utilisation of simple horizon ratio information in adult Americans, but his work was not extended to children. It should be borne in mind that the simple horizon ratio obtains only for a level, unbounded ground plane, and would therefore not hold for the pictures in which a mountain is suggested by the position of the horizon line.

Of the static depth cues, only interposition appeared to be conveying pictorial depth information to the Malawian children, and it appears necessary to look to the utilisation of other sources of information in order to understand the development of pictorial depth perception in Malawians.

d. The role of familiarity in recognition and the perception of pictorial depth

In Chapter One, research was presented which demonstrated that drawings of common objects are recognised by people who have had little or no exposure to pictures (Hochberg and Brooks 1962, Jahoda et al 1977, Deregowski, Muldrow and Muldrow 1972). Deregowski found that when Bisa schoolchildren and adult males were shown photographs of model animals and were asked to point to the appropriate
model in an array of model animals, the subjects displayed
greater difficulty with unfamiliar animals than with animals
that were familiar to them. It has also been shown that
drawings of familiar items elicit greater perception of
pictorial depth than drawings of unfamiliar items. For
example, modifications of the Hudson pictures have elicited
more responses indicative of pictorial depth perception than
the original pictures (Omari and MacIntie 1974, Opolot
1976, Hagen and Johnson 1977, Leach 1975). Results
presented herein (Chapter Four) are also in agreement, and
extend previous findings by showing that even uneducated
children perceive depth in drawings of familiar scenes.

The same holds true for the interpretation of diagrams.
A study of the spatial interpretation of diagrams of
structures (Nicholson and Seddon 1977a & b) showed the
necessity of comprehending the spatial structure in its
three-dimensional form in order for the interpretation of
the diagrams to be correct. They investigated the
perception of depth in hexagonal and cuboid structures and
found a rather low level of comprehension among Nigerian
secondary school students as compared with English secondary
school students. In a subsequent experiment, the authors
(Nicholson, Seddon and Worsnop 1977b) used stereoscopic
pictures, planoscopic pictures and models in an
instructional program intended to bring about an improvement
in the Nigerian boys' performance. They found differential
effectiveness of the training programs among Yoruba and
Hausa students, but the use of stereoscopic pictures was
effective in enhancing pictorial depth perception in both
groups. A combination of diagrams and models was also
effective for the Hausa students, but a program using only
models was not.

In effect this suggests that in order to interpret
spatial relations depicted in a drawing of a structure it is
necessary to comprehend the three-dimensional spatial
relationships in the real objects portrayed. Knowledge of
the latter is an essential prerequisite of the former at the
level of ability with which we have been dealing, but it
does not imply the former. The diagram is an abstraction of
the model, and the reader must be familiar with the features
of the model displayed in the diagram in order to recognise
them in the diagram.

The empirical data thus supports a theoretical position
that pictorial representation of three-dimensionality is not
purely conventional, but that the same kind of information
is available in a drawing as in a real scene. However, it
is necessary for the naive observer to be familiar with the
relevant features of the three-dimensional layout in order
to correctly interpret the two-dimensional layout. As
pictorial sophistication increases through wide-ranging
exposure to and interpretation of pictures, the ability to
deduce three-dimensional structure from the two-dimensional
representation develops.

The association of the rather broad variables of family
background and education with pictorial depth perception may well be in part at least due to the greater exposure to a variety of objects in the real world. In Gibsonian terms, greater exposure to a variety of environments and views of objects gives greater opportunity for the knowledge of invariants which can then be recognised in drawings. Gibson argues that "...a picture is a surface so treated that it makes available a limited optic...array of persisting invariants of structure that are nameless and formless" (1979, p.270-271). He assumes that "...some of the invariants of an array can be separated from its perspective structure, not only when the perspective keeps changing, as in life, but also when it is arrested, as in a still picture." He gives an example of a child playing with the family cat, the child perceives the invariant cat, not one particular perspective of the cat, and thus when he first sees a picture of a cat, he is prepared to pick up the invariants, through which he gets information for the persistence of that mobile layout of surfaces. It follows that if the child has not perceived different perspectives of objects and layouts, he will not be prepared to pick up the invariants displayed in a picture and relate them to a meaningful form.
Photographs are generally considered to be good conveyers of pictorial information. They have a point-to-point correspondence with the scene they portray and if the photograph is in colour, it captures much of the available optical information. However, this thesis has been concerned in the main with black-and-white pictures, and the black-and-white photograph is an abstraction in which informational content is already greatly reduced, although the optic array is preserved. Naive observers display difficulty (Herskovits 1959, Fuglesang 1978) in interpreting black-and-white photographs, and their problem appears to be that of separating out features from the background.

Photographs contain more optically faithful information than outline drawings, for, although the outline drawing may be an entirely faithful representation (for example the outline may have been traced from the photograph) some information is lost. Some of the lost information may be replaced by shading the line drawing, or by line and tone. A cartoon is least optically faithful and it might be predicted that it would be a less effective means of conveying information than a photograph, yet it can convey information more rapidly than a photograph to sophisticated viewers. This has been demonstrated experimentally by Ryan and Schwartz (1956). They tested the speed of recognition.
of objects in photographs, shaded drawings, line drawings and cartoons. The objects were (1) a human hand against a light background, in four different orientations; (2) a group of five electrical knife switches with one switch open and the rest closed; (3) a cut-away model of the valves of a steam engine. There were four positions for each of the three pictures, and each of these twelve configurations were reproduced as a photograph, a line drawing, a shaded drawing and a cartoon. The drawings were reproduced from the photograph. Recognition was fastest for the cartoons, slowest for the line drawings, with photographs and shaded drawings intermediate. The cartoons were the least faithful representations of the optical arrays from the real objects, but they highlighted the features necessary for correct identification.

There is thus support for the view that picture identification proceeds by a process of feature identification. It is suggested that perception of pictorial depth proceeds in a similar way. In addition to identification of objects and figures in the picture, depth information must be identified, and a strategy of paying attention to the information for depth rather than to the information for flatness must be applied. In the face of inadequate or conflicting information for depth, inappropriate strategies might be employed in order to answer depth-related questions, for example, about the relative distances of objects. The development of
strategies will be considered in the following section.

f. The development of strategies for the interpretation of pictorial depth

One of the strategies that must be acquired in order to accurately perceive depth in a drawing is that of ignoring the information for the picture plane. Pirenne (1970) has shown how this information is taken into account in situations where the observer views the picture from an incorrect station point, and is nevertheless able to perceive the picture in a relatively undistorted fashion. A photograph of a poster or scene taken from an incorrect or oblique station point by contrast gives a distorted view of the subject matter. The term 'ignoring' is thus perhaps a misnomer, and the information for the picture plane has to be registered in order for the viewer to adopt an attitude appropriate to picture viewing. Once such an attitude has been adopted, the information for depth can be maximally utilised.

Under restricted viewing conditions, removal of information for the picture plane improves perception of depth. Information for the picture plane comes from binocular cues which attest to the presence of a surface and the equal distance of the forms on the surface. Motion parallax information, available even when the picture is viewed monocularly, provides evidence for the equal distance
of the forms, because when the head is moved, the light from the picture surface moves across the retina at an equal rate. Yonas and Hagen's (1973) findings and the results of experiment 9 provide evidence that subtraction of motion parallax information enhanced accuracy of pictorial size judgements in young children. The analysis also showed that adults adopted a strategy of ignoring the information for the picture plane.

Against these findings are those of Deregowski and Byth (1970) who did not find perception of depth enhanced by removal of background information. Deregowski and Byth made transparencies of the first two pictures of Hudson's test and displayed them in an apparatus designed by Gregory (1966). The transparencies were back-illuminated and displayed to one eye by a mirror. A small light source, which appeared to lie in the figure, but which could be moved closer to or farther from the viewer, was seen with both eyes and could be adjusted so as to lie at the same apparent distance as any selected part of the figure. Scottish students responded three-dimensionally to the second card which contained the cue of superimposition, but the Zambian domestic servants remained 2D throughout. The explanation for the difference in findings most probably lies in the nature of the displays, and the authors suggest that the depth cues were too weak to elicit three-dimensional responding. The displays used by Yonas and Hagen and in the present study were of solid objects as
opposed to line drawings, and the photographic transparencies provided multiple cues to depth, whereas the Hudson drawings did not.

It is suggested that the failure of young Malawians to perceive pictorial depth is a result of their attending to the information for the picture plane and thus preventing the operation of constancy scaling mechanisms. Some attempts at training for perception of pictorial depth suggest that the failure to perceive pictorial depth is a result of a failure to apply the correct strategy. For example, Deregowski (1974) found that Zambian Primary schoolboys who at first responded two-dimensionally to his (1968) diagrams, almost all built three-dimensional models in response to similar diagrams viewed through a stereoscope. When, immediately after, the boys were given a conventional diagram to build under normal viewing conditions, they were more likely to respond three-dimensionally. This suggests that the stereoscopic demonstration illustrated the application of the strategy of ignoring the picture plane, and the boys could then apply this strategy to the viewing of the drawing under normal viewing conditions.

Leach (1975) used a system of moving cut-out squares and circles nearer to and farther from the subject by means of strings, in order to teach children that 1) the more distant of two shapes is partly hidden by the nearer shape; 2) as a shape is moved away it appears to grow smaller; 3)
as a more distant shape is moved away it becomes more
elevated relative to a stationary shape; 4) as two shapes
are moved away they tend to converge, as do the strings from
which they are suspended. He found significant improvements
in Zimbabwean Primary schoolchildren's perception of
pictorial depth after the teaching sessions. Leach appears
to have successfully taught the children to attend to the
information for depth.

The success of these training techniques lies in
directing attention to the available information for depth.
Deregowski, Muldrow and Muldrow's (1972) observation that
Mekan paid more attention to the surface fabric than to the
surface marking, and Fuglesang's (1979) comment that to
villagers the most striking feature of a photograph was its
straight edges, both indicate that features other than those
which specify depth were salient to villagers. Before
training, information for depth used by the artist was not
relevant to the subject's perception and the training
methods succeeded in making it relevant. The present
research and the results for Ghanaian subjects of McGurk and
Jahoda (1975) indicate that there is lack of sensitivity to
individual depth cues at any one age, which can also be
explained in terms of a lack of relevance to the subjects.
If the depth information becomes salient, the picture is
recognised as representing three-dimensionality and size
relations will be interpreted more accurately, through the
operation of size constancy mechanisms.
g. The role of constancy

Although not designed as a test of constancy, the experiment reported in Chapter Six does give indications of constancy. In some constancy experiments, the subject is shown the standard object and is asked to judge whether or not each one of a number of examples of the variable is the same size as the standard. When the variable is farther from the subject than the standard, operation of perfect constancy would lead the subject to choose a variable the same physical size as the standard even though the retinal angle subtended by the variable would be smaller than that subtended by the standard. Underconstancy is exhibited when the subject chooses a variable which is larger than the standard. In experiment 9, the more distant object was always larger than the nearer object, and if there was perfect constancy the more distant object should have been chosen as larger all the time. As discussed in Chapter Three, certain experimental conditions tend to reduce constancy, and in the present experiment the monocular viewing and restricted cues would do this. Adults and 7-8 year olds gave at least 95% correct responses in the 3-dimensional motion parallax present condition, which gave the greatest information for depth. Thouless (1933) and Beveridge (1935) found greater size constancy in groups of Indian and West African students than in European students. If the Malawian students exhibited greater size constancy
than the American students tested by Yonas and Hagen (1973),
the mean percentages correct under the three-dimensional
motion parallax present condition should be higher for
Malawians. This is not the case, as can be seen from Table
7.1 in Appendix D. The mean percentages correct are lower
for Malawians, and although the difference for the two older
groups of subjects is very slight, for the youngest group it
is quite marked. In normal constancy experiments, viewing
is binocular, whereas in the present experiment viewing is
monocular, and it could be that the reduction in information
from the binocular to the monocular viewing differentially
reduced accuracy. It must also be considered that for the
youngest group the test objects might have been unfamiliar,
as the children might not have encountered geometrical
shapes other than circles outside nursery school; if this
were so, it would have tended to lower scores.

The lower percentages correct for two-dimensional as
compared with three-dimensional conditions and for children
as compared with adults indicate less constancy. This is in
accordance with previous research which has shown lower size
constancy in response to photographs than test objects and
lower size constancy under monocular than under binocular
viewing conditions (Leibowitz, Bussy and McGuire 1957,
Winters and Baldwin 1971). The indications of
underconstancy in the children are also in accordance with
the developmental work on Western children and with the
findings of Mundy-Castle and Nelson (1962) for black nursery
school children.

Adults were more often correct than children and the objects themselves more often elicited correct responses than photographs of the objects. There was an increase in correct responses with age under both 2- and 3-dimensional viewing conditions. Comparison of judgements made under the 3-dimensional conditions showed that children's judgements were more accurate when motion parallax information was available. Adults appear to place less reliance than children on kinetic information for depth and this would suggest that they rely instead either on static depth information or on another system of estimation which operates independent of depth information.

Motion parallax has been shown to provide information for depth even in the absence of other depth cues. Rogers and Graham (1979) used stimulus displays consisting of computer-generated random-dot patterns that could be transformed by each movement of the observer or the oscilloscope on which they were displayed, and they succeeded in simulating the relative movement information produced by a three-dimensional surface. The authors also found that in a stereoscopic matching task, the perceived depth from the parallax transformations was in close agreement with the degree of relative image displacement, as well as producing a compelling impression of three-dimensionality not unlike that found with random-dot stereograms.
However, as far as size judgments are concerned, motion parallax only provides information as to which of two objects is more distant. On the other hand, elimination of motion parallax results in information for the equal distance of the objects, and such is the case when viewing pictorial displays. It appears that American adults develop an ability to utilise information for depth other than that provided by movement. The information they utilise must be the static information, which can also be displayed pictorially. Malawian adults did not fully utilise the static information in three-dimensional displays in experiment 9, and it follows that they will be less likely to pick it up in two-dimensional displays.

American subjects have also been demonstrated to be able to analyse different sources of size and distance information in a pictorial display (Uhlarik et al, 1980), and in the course of their work, Uhlarik et al demonstrated that size was scaled relative to a perceptual unit independently of distance. The authors examined the effects of instructional sets (objective, phenomenal, projective and retinal) on the judged sizes of blocks placed at various 'distances' in a pictorial array. The surface on which the blocks were superimposed was a dark blue cloth, regularly textured with white polka dots, which was photographed from a height of .7m above the array. Subjects were shown back-projected slides of the array, and were asked to make a magnitude estimation of the size of the block in each
photograph, the smallest block at the closest distance being used as the standard of "10 units". Subjects receiving the objective, phenomenal or projective sets of instructions were encouraged to "...think of this surface as a road or sidewalk going off into the distance, or as a carpet on the floor. Imagine it in the way that gives you the greatest feeling of depth, or three-dimensionality." Subjects receiving retinal instructions were told to ignore the receding surface. Each subject viewed the six blocks at each of four distances, and the time taken to make each estimation was recorded. Magnitude estimations of size were consistent with previous studies of size constancy in three-dimensional arrays, with objective instructions leading to slight overconstancy, phenomenal instructions to near-perfect constancy, projective instructions to underconstancy and retinal instructions to greater underconstancy. Analysis of the reaction times revealed that reaction time increased with the actual size of the blocks, but was not affected by perceived distance. There was an interaction between size and distance for the projective and retinal instructions, with reaction time increasing with the size of the object, but no such interaction under the objective and phenomenal instructions. The authors interpret their findings as showing that "...in order to scale the size of an object relative to a standard unit, an observer must estimate the number of perceptual units in the comparison figure. The more perceptual units
the comparison contains, the longer the time required (p. 66). However, the instructional set altered the perceptual scale unit. Objective and phenomenal instructions required scaling the distal sizes of the comparison relative to a scale unit of a constant distal size. Projective and retinal instructions required scaling of the proximal sizes of the comparison figures relative to a standard scale unit.

Their findings are consistent with Gibson's (1950) approach to size constancy. According to Gibson, size constancy "is a by-product of the constant scale of the visual world at different distances. Scale, not size, is actually what remains constant in perception" (1950, p. 181). Gibson (1979) expresses this concept of scale in terms of 'invariant ratios' which are picked up by the observer, such as that provided by the constant number of texture elements occluded by an object, however distant. Gibson goes on to suggest that "both size and distance are perceived directly. The old theory that the perceiver allows for the distance in perceiving the size of something is unnecessary" (1979, p. 162).

In Chapter Three, reference was made to Weinstein's (1957) study, in which he demonstrated that American adults were able to make a good estimate of the size of a stake even without texture information. This suggests that they were able to erect a scale largely on the basis of the information that the picture represented a field stretching
away in the distance. There are indications that pictorially educated subjects make this assumption even in the absence of instructions as to the three-dimensional space represented, but it is unlikely that young children and pictorially uneducated adults do so. For the latter, therefore, the static information for depth would have to be more plentiful, or the scene portrayed more obviously three-dimensional through its familiarity to the viewer in the three-dimensional world, in order for the viewer to make the assumption of three-dimensionality. Very few of the studies of Africans have used pictures of familiar scenes with plentiful depth cues and also instructed subjects that they were going to see such a scene. One that did so was that of Leach (1975), and his subjects displayed high percentages of three-dimensional responding.

Rock, Shallo and Schwartz (1978) argue that "the traditional pictorial cues such as perspective or texture gradients are neither a necessary nor a sufficient basis for the perception of an extended ground plane. They hypothesised that the picture must be recognised as representing a ground plane in order to lead to an impression of depth. In order to test their hypothesis, they showed subjects a photograph of a field of grass, without any horizon or sky; 10 of the 32 University students tested did not recognise the photograph. A standard white square and a comparison white square were projected on the screen, the standard in the 'foreground' left, and the
variable in the right 'rearground'. Subjects adjusted the variable square to match the apparent size of the standard in an ascending and a descending trial. There was a significant difference between the comparison setting and the real size of the standard for the subjects who recognised the picture, but no difference for those who did not recognise the picture. The authors contend that certain features of an array (horizon, sky, texture, perspective pattern etc.) are first detected prior to any impression of depth. The recognition that then occurs brings with it the impression of depth.

The fact that Western adults are able to make estimations of size according to retinal angle in size constancy experiments has been taken to imply the adoption of an analytic attitude, and it is this tendency to analyse that has been proposed as the explanation for the lower constancy of Western adults as opposed to non-Westerners. Constancy scaling is a compromise between the actual size or shape of an object and the retinal angle it subtends, and Western adults are able to alter the extent of this compromise according to instructions. There have been no studies of the effects of instructions on constancy scaling in African subjects, but studies of Western children indicate that the ability to vary estimates according to instructions does not develop until about age 12 years (Rapoport 1967).

Studies of pictorial depth perception have, on the
other hand, shown a tendency for Western subjects to demonstrate greater perception of depth than Africans (Hagen and Jones 1978, Jahoda and McGurk 1974a, McGurk and Jahoda 1975). There thus appears to be a relationship between high constancy (and implicit constancy) and low pictorial depth perception, which is surprising, because it would be expected that viewers who exhibit high constancy in the three-dimensional setting would also exhibit high constancy in the two-dimensional setting. This problem can be resolved if constancy is considered in a framework of an ability to analyse information for depth. A lack of such an ability would result in low constancy in the presence of only static information for depth. This would be especially likely in subjects who displayed a reliance on kinetic depth information. A lack of analysis and a reliance on kinetic information implies the salience of the information for the equal distance of the forms on the picture surface, and hence two-dimensional picture perception. The ability to analyse visual information and make size judgements according to instructions could be tested directly by conducting a standard size constancy experiment with objective, phenomenal and retinal instructions. It would be predicted that educated adult Malawians' size judgements would differ less under different instructions than educated adult Westerners', and that uneducated Malawians would display least difference.

The lack of an analytic attitude would also result in
a tendency to draw objects as they are known to be rather than as they are seen to be. There would thus be a tendency for the non-Westerner to expect the size of an object in a drawing to be the size as portrayed, whereas the Western viewer expects the picture to portray the perspective size of an object. In many cases, the artist does not work out the perspective geometry, instead he draws what looks natural, and this is a compromise between the perspective size and the perceived size. A lack of a habit of attending to the perspective size of an object was noticed by the Art lecturer at Chancellor College, who found that Malawian teenagers had difficulty in perceiving a more distant object as smaller than a nearer one, even when they used the usual aid of a pencil held at arm's length to make comparisons (Oman, personal communication). This creates difficulties for the artist who is attempting to draw in perspective.

In 1931, Thouless (1931b) wrote "The essential fact of phenomenal regression is that an important factor in the determination of perceptual response is the nature of the physical object so far as the conditions of perception are such that the observing subject has any cues as to what are the characters of the physical object." If two observers have different regression to the real object, or size constancy, they will perceive the sizes of distant objects differently, and there is no reason not to extend this to their perception of size in drawings.

There is some empirical support from the present
research for an association of good constancy with
two-dimensional picture perception. If Myambo's (1972)
finding of higher shape constancy in uneducated Malawians
and lower constancy in educated Europeans, with educated
Malawians intermediate is indicative of a general trend in
constancy, it would be predicted that a corresponding order
would emerge in pictorial depth perception, with the
educated Europeans exhibiting greatest perception of
pictorial depth and the uneducated Malawians least. This
was the case in the comparison of the three groups of 13-14
year olds on the 'huts' version of the Jahoda-McGurk test,
but the schoolchildren in other age groups were not shown to
be consistently more three-dimensional than the unschooled
in that test (test scores were, however, mostly at chance
level). The schoolchildren were more three-dimensional than
the unschooled in their responding to the modified version
of the Hudson test.

There is also evidence of a tendency towards higher
constancy and lower pictorial depth perception in less
advantaged Westerners. Mundy-Castle and Nelson found just
such a relationship in the rather isolated group of Knysna
forest workers. Jones (1974) found less pictorial depth
perception among more isolated Labrador boys than among
those living in the town. This framework also makes for an
understanding of the possible role of family background and
education on the development of pictorial depth perception.
This role might be twofold, firstly exposing the child to a
greater variety of perceptual experiences (including books) through greater mobility, and secondly exposing him to a greater flexibility of interpretation.

Conclusions

The testing methods used by Hudson and by Jahoda and McGurk were shown to be sensitive to alterations in pictorial content with constant pictorial structure. Content familiarity significantly improved subjects' perception of depth in the Hudson pictures, and pictorial fidelity improved subjects' size scores with the modifications of the Jahoda-McGurk pictures. Experimental manipulation of information for the picture plane provided evidence that children were not applying a strategy of selectively attending to information for depth in pictorial displays.

Age and education were shown to be associated with greater perception of pictorial depth. Evidence was presented for an effect of education, but it was not a powerful one. An explanation for the weakness of education was thought to be in part the lack of attention to art in Primary school. Schoolchildren who had a parent who had received at least four years of Primary school education were more likely to give responses indicative of pictorial depth perception than children whose parents had received little or no education. It was proposed that parental
influence was exerted through a greater exposure of the child to a variety of perceptual experiences and to a flexibility of interpretation.

The cue of interposition was utilised to a greater extent by younger children than the cue of linear perspective, and the effectiveness of interposition in these drawings was thought to result from the degree of occlusion of the rearground object by the foreground object as opposed to the occlusion of landscape lines. There was no evidence for the effectiveness of any of the other depth cues used, except for a weak influence of texture gradient. The use of horizon ratio information was discussed, and the possibility was considered that the positionning of the horizon so as to avoid intersection of the objects and figures deprived subjects of depth information and depressed size scores in the Chapter Five experiments.

There was evidence that Malawian children and adults relied on kinetic information in making size judgements in three-dimensional displays although the reliance on this information reduced with age. Adults were less influenced by information for the picture plane than children and made more accurate size judgements in the pictorial displays. However, the picture plane information did still affect adults' judgements when depth information was weaker.

Further research is needed into the most effective methods of teaching pictorial depth perception both in school and out. In schools, teaching is necessary in order
for students to maximally utilise the pictorial information presented to them. This appears to be particularly true when drawings of unfamiliar material are used. Training techniques which have been shown to be successful have either used a stereoscope (Deregowski 1974, Nicholson and Seddon 1977b) or a physical demonstration of the operation of static cues to depth (Leach 1975). There is still much to be learned about the relative effectiveness of photographs, line drawings, block-outs, shaded drawings and cartoons as didactic tools in different situations. When it comes to presentation of information to the pictorially uneducated, restriction of artistic licence, use of photographs with neutral backgrounds, inclusion of familiar items and situations, and exclusion of abstract conventions such as shock waves and lines indicating movement can be expected to increase the chances of interpretation of depth as intended by the artist. By the end of Primary school, accurate identification of familiar objects and interpretation of depth in drawings of familiar scenes can be expected when the drawings are not gross aberrations from the optical array from a real scene.

The lack of differential effectiveness of pictorial depth cues in eliciting three-dimensional responses to pictures and the tendency to be influenced by picture plane information led to the consideration of broader variables which might influence the development of pictorial depth perception. It was suggested that greater constancy might
have resulted in a tendency for Malawians to interpret pictures literally, and therefore two-dimensionally, in the experiments with outline drawings in which depth information was weak. In pictures where depth information from cues or from pictorial context was greater, depth perception improved, and in the modified version of the Hudson test, was good by the end of Secondary school.
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APPENDIX A

1. Complete set of 'huts' pictures with texture gradient used in experiment 4.
2. Complete set of huts pictures having the less elevated rear ground hut, used in experiment 5.
3. Complete set of 'figures' pictures used in experiment 7.

Child - child

Child - adult
Figures task. Linear perspective condition.

Adult - child

Adult - adult
Child - adult

Child - child
Child - child

Adult - child
Figures task, training pictures
Figures task, training pictures
APPENDIX B

Worked examples

Chapter Four

1. Chi-square test on data in Table 4.1
   Test the null hypothesis that correct identification is not associated with either card.

   Numbers of subjects correctly identifying all items in cards 1 and 2.

<table>
<thead>
<tr>
<th>Correct</th>
<th>Incorrect</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card 1</td>
<td>338</td>
<td>186</td>
</tr>
<tr>
<td>Card 2</td>
<td>432</td>
<td>94</td>
</tr>
<tr>
<td>Totals</td>
<td>770</td>
<td>280</td>
</tr>
</tbody>
</table>

   \[ \chi^2 = \frac{1050 \times (432 \times 186 - 338 \times 94)}{524 \times 526 \times 770 \times 280} \]
   \[ = 41.70 \]
   \[ \text{df}=1, \ p<0.001 \]

2. McNemar test for the significance of changes in three-dimensional responses from card 1 to card 2.
   Data in figure 1.

   Age group 9-10 years

<table>
<thead>
<tr>
<th>Card 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D 2D</td>
</tr>
<tr>
<td>Card 1</td>
</tr>
<tr>
<td>2D 24</td>
</tr>
<tr>
<td>3D 1</td>
</tr>
</tbody>
</table>

   \[ \chi^2 = \frac{(\text{}/A - D/) - 1)^2}{A + D} \text{ with df}=1 \]
   \[ = 21^2 / 25 \]
   \[ = 18.38 \]
3. Test for linear trend in proportions on data in Table 4.2

<table>
<thead>
<tr>
<th>Age</th>
<th>6-8</th>
<th>9-10</th>
<th>11-12</th>
<th>13-14</th>
<th>15-16</th>
<th>17-18</th>
<th>19-20</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D</td>
<td>28</td>
<td>17</td>
<td>14</td>
<td>27</td>
<td>44</td>
<td>47</td>
<td>29</td>
<td>206</td>
</tr>
<tr>
<td>2D (a)</td>
<td>37</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>78</td>
</tr>
<tr>
<td>Total (n)</td>
<td>65</td>
<td>24</td>
<td>20</td>
<td>34</td>
<td>53</td>
<td>54</td>
<td>34</td>
<td>284</td>
</tr>
</tbody>
</table>

\[ p = \frac{a}{n} \]

\[ \begin{array}{cccccccc} 
\text{Score} & -3 & -2 & -1 & 0 & +1 & +2 & +3 \\
\text{n} & 585 & 96 & 20 & 0 & 53 & 216 & 306 & 1276 \\
\text{a} & 111 & 14 & 6 & 0 & 9 & 14 & 15 & \\
\text{n} & 195 & 48 & 20 & 0 & 53 & 108 & 102 & 526 \\
\end{array} \]

\[
\begin{align*}
\text{Num} &= \sum aX - (\bar{X}^a)(\sum nX) / N \\
&= 169 - 78 \times 526 / 284 \\
&= 24.54
\end{align*}
\]

\[
\begin{align*}
\text{Den} &= \sum nX^2 - (\sum nX)^2 / N \\
&= 1276 - 974.21 \\
&= 301.79
\end{align*}
\]

\[
\begin{align*}
\text{b} &= \frac{24.54}{301.79} \\
&= 0.08131
\end{align*}
\]

\[
\begin{align*}
\text{S.E.} &= \sqrt{\frac{pq}{\text{Den}}} \\
&= \sqrt{0.2746 \times 0.7254 / 301.79} \\
&= 0.02569 \\
\text{Z} &= \frac{0.08131}{0.02569} \\
&= 3.16
\end{align*}
\]

\[ p < 0.05, \text{ 1-tailed, reject the null hypothesis.} \]
4. Test for association of pictorial depth perception with education using Cochran's Criterion (Table 4.3).

<table>
<thead>
<tr>
<th>Age</th>
<th>3D</th>
<th>2D</th>
<th>Tot</th>
<th>Propn.</th>
<th>$d_i$</th>
<th>$p_i$</th>
<th>$q_i$</th>
<th>$P_{ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8</td>
<td>Sch</td>
<td>24</td>
<td>10</td>
<td>34</td>
<td>0.7059</td>
<td>0.0488</td>
<td>0.6812</td>
<td>0.3188</td>
</tr>
<tr>
<td></td>
<td>Unsch</td>
<td>23</td>
<td>12</td>
<td>35</td>
<td>0.6571</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>47</td>
<td>22</td>
<td>69</td>
<td>0.6812</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-10</td>
<td>Sch</td>
<td>20</td>
<td>5</td>
<td>25</td>
<td>0.8000</td>
<td>0.1500</td>
<td>0.7333</td>
<td>0.2667</td>
</tr>
<tr>
<td></td>
<td>Unsch</td>
<td>13</td>
<td>7</td>
<td>20</td>
<td>0.6500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>33</td>
<td>12</td>
<td>45</td>
<td>0.7333</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-12</td>
<td>Sch</td>
<td>25</td>
<td>7</td>
<td>32</td>
<td>0.7813</td>
<td>0.0166</td>
<td>0.7755</td>
<td>0.2245</td>
</tr>
<tr>
<td></td>
<td>Unsch</td>
<td>13</td>
<td>4</td>
<td>17</td>
<td>0.7647</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>38</td>
<td>11</td>
<td>49</td>
<td>0.7755</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-14</td>
<td>Sch</td>
<td>31</td>
<td>11</td>
<td>42</td>
<td>0.7381</td>
<td>0.0013</td>
<td>0.7377</td>
<td>0.2623</td>
</tr>
<tr>
<td></td>
<td>Unsch</td>
<td>14</td>
<td>5</td>
<td>19</td>
<td>0.7368</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>45</td>
<td>16</td>
<td>61</td>
<td>0.7377</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-16</td>
<td>Sch</td>
<td>60</td>
<td>11</td>
<td>71</td>
<td>0.8451</td>
<td>0.0951</td>
<td>0.8182</td>
<td>0.1818</td>
</tr>
<tr>
<td></td>
<td>Unsch</td>
<td>21</td>
<td>7</td>
<td>28</td>
<td>0.7500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>81</td>
<td>18</td>
<td>99</td>
<td>0.8182</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-18</td>
<td>Sch</td>
<td>83</td>
<td>9</td>
<td>92</td>
<td>0.9022</td>
<td>0.1091</td>
<td>0.8760</td>
<td>0.1240</td>
</tr>
<tr>
<td></td>
<td>Unsch</td>
<td>23</td>
<td>6</td>
<td>29</td>
<td>0.7931</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>106</td>
<td>15</td>
<td>121</td>
<td>0.8760</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Age $W_i$, $w_{di}$, $w_{pq}$, $p_i$ = difference in proportions $w_i= (n_1n_2)/(n_1+n_2)$

Weighted mean difference $d = \frac{\sum (w_{di})}{w}$ where $w=\sum w_i$

$S.E. = \sqrt{[\frac{(\sum w_{pq})}{w}] /w}$

$C.R. = \frac{d}{S.E.} = \frac{0.07420}{0.04194} = 1.769$

$p = 0.0384$, 1-tailed.
5. Cochran's Q test for the significance of differences between matched samples (Table 4.4).

Example for age group 9-10 years.

3D responses were given a score of 1, 2D responses score 0.

<table>
<thead>
<tr>
<th>Response to card</th>
<th>Row total</th>
<th>No of cases</th>
<th>$S$</th>
<th>Sq. of ro tot</th>
<th>$S^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$T_{25}$</th>
<th>36</th>
<th>29</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T^{625}$</td>
<td>1296</td>
<td>841</td>
</tr>
<tr>
<td>$\Sigma T^r$</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>$\Sigma T^r$</td>
<td>2762</td>
<td></td>
</tr>
</tbody>
</table>

$Q = (m - 1) \times \frac{\sum T^r - T^b}{mT - \Sigma S^2}$

$= 2 \times 3 \times 2762 - 90^2$

$= \frac{3 \times 90 - 230}{242}$

$= 9.3$
6. Pairwise comparison of matched samples (Table 4.4).

Example for Age group 9-10 years

<table>
<thead>
<tr>
<th>Response to card</th>
<th>No of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

There are three possible pairwise comparisons, L=3, and a set of confidence intervals for all pairwise differences with an overall level of significance of \( \alpha = 0.05 \) is constructed:

\[
Z_{0.05/3} = Z_{0.05/4} \approx 2.41
\]

The confidence interval for the comparison of card 2 with card 3 is computed as follows:

\[
\left[ \frac{36}{44} - \frac{25}{44} \right] \pm 2.41 \left[ \frac{1}{44} \left( \frac{36}{44} + \frac{25}{44} - \left( \frac{36}{44} - \frac{25}{44} \right)^2 \right) \right]^{1/2}
\]

and we obtain

\[
0.25 \pm 2.41 \left( \frac{1}{44} \left( 1.38 - 0.0625 - 1.045 \right) \right)^{1/2}
\]

which is \( 0.25 \pm 0.19 \)

and the confidence interval is \( 0.06 \leq \pi_2 - \pi_3 \leq 0.44 \)

The proportions are significantly different when the confidence interval for the difference in proportions does not include zero.
Chapter Five

7. 2-way analysis of variance, age x schooling, for size scores in Table 5.1

Table of means, sample size in parentheses.

<table>
<thead>
<tr>
<th>Age</th>
<th>School</th>
<th>No school</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>10.38</td>
<td>7.63</td>
<td>(8)</td>
</tr>
<tr>
<td>7-8</td>
<td>8.2</td>
<td>8.47</td>
<td>(15)</td>
</tr>
<tr>
<td>10-11</td>
<td>7.67</td>
<td>7.87</td>
<td>(15)</td>
</tr>
<tr>
<td>13-14</td>
<td>7.73</td>
<td>8.73</td>
<td>(15)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Age</td>
<td>16.226</td>
<td>3</td>
<td>5.41</td>
<td>0.79</td>
</tr>
<tr>
<td>SchxAge</td>
<td>2.58</td>
<td>3</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>664.82</td>
<td>98</td>
<td>6.78</td>
<td></td>
</tr>
</tbody>
</table>

Total 683.62 105

No main effects or interaction.

8. 2-way analysis of variance, age x schooling for spatial scores in Table 5.2

Table of means of spatial scores

<table>
<thead>
<tr>
<th>Age</th>
<th>School</th>
<th>No school</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>10.75</td>
<td>3.63</td>
<td>7.19</td>
</tr>
<tr>
<td>7-8</td>
<td>20.87</td>
<td>11.4</td>
<td>16.14</td>
</tr>
<tr>
<td>10-11</td>
<td>21.6</td>
<td>15.27</td>
<td>18.44</td>
</tr>
<tr>
<td>13-14</td>
<td>21.4</td>
<td>17.27</td>
<td>19.34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>1195.523</td>
<td>1</td>
<td>1195</td>
<td>25.3</td>
</tr>
<tr>
<td>Age</td>
<td>1741.837</td>
<td>3</td>
<td>580.61</td>
<td>12.3</td>
</tr>
<tr>
<td>Contrast 1.</td>
<td>1579.7</td>
<td>1</td>
<td>1579.1</td>
<td>33.47</td>
</tr>
<tr>
<td>2.</td>
<td>153.6</td>
<td>1</td>
<td>153.6</td>
<td>3.25</td>
</tr>
<tr>
<td>Sch x Age</td>
<td>108.539</td>
<td>3</td>
<td>36.17</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>4625.775</td>
<td>98</td>
<td>47.20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7671.774</td>
<td>105</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant main effects for age and education
9. 1-way analysis of variance of data in Table 5.5.

Table of means of size scores

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawian schoolchildren</td>
<td>8.2</td>
<td>15</td>
</tr>
<tr>
<td>European schoolchildren</td>
<td>10.6</td>
<td>15</td>
</tr>
<tr>
<td>Malawian unschooled</td>
<td>8.47</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>51.911</td>
<td>2</td>
<td>25.955</td>
<td>3.25</td>
</tr>
<tr>
<td>Contrast</td>
<td>51.3</td>
<td>1</td>
<td>51.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Residual</td>
<td>335.733</td>
<td>42</td>
<td>7.9936</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>387.644</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ F_{2,44}(0.05) = 3.23 \]

Significant main effect

10. Table of means of spatial scores

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawian schoolchildren</td>
<td>20.87</td>
<td>15</td>
</tr>
<tr>
<td>European schoolchildren</td>
<td>23.67</td>
<td>15</td>
</tr>
<tr>
<td>Malawian unschooled</td>
<td>11.4</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>1239.644</td>
<td>2</td>
<td>619.82</td>
<td>24.5</td>
</tr>
<tr>
<td>Contrast</td>
<td>1131.57</td>
<td>1</td>
<td>1131.57</td>
<td>46.7</td>
</tr>
<tr>
<td>Residual</td>
<td>1062.667</td>
<td>42</td>
<td>25.3015</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2302.311</td>
<td>44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ F_{2,44}(0.01) = 5.18 \]

11. T-test for differences between means of size scores on figures and huts pictures.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figures</td>
<td>7.133</td>
<td>15</td>
</tr>
<tr>
<td>Huts</td>
<td>4.733</td>
<td>15</td>
</tr>
</tbody>
</table>

\[ H_0: \mu_{\text{figs}} = \mu_{\text{huts}} \]
\[ H_1: \mu_{\text{figs}} > \mu_{\text{huts}} \]
\[ t_{\text{calc}} = 3.42 \]

Reject \( H_0 \)

Spatial scores

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figures</td>
<td>14.13</td>
<td>15</td>
</tr>
<tr>
<td>Huts</td>
<td>14.40</td>
<td>15</td>
</tr>
</tbody>
</table>

No difference between means therefore accept the null hypothesis.
12. 2-way analysis of variance for size scores on tins and huts pictures.

<table>
<thead>
<tr>
<th>Table of means (sample size = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-8 13-14 Adults</td>
</tr>
<tr>
<td>Tins 3.6 3.8 5.3</td>
</tr>
<tr>
<td>Huts 2.9 2.27 5.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tins/Huts</td>
<td>6.944</td>
<td>1</td>
<td>6.944</td>
</tr>
<tr>
<td>Age</td>
<td>119.022</td>
<td>2</td>
<td>59.511</td>
</tr>
<tr>
<td>T/H x Age</td>
<td>189.333</td>
<td>84</td>
<td>2.25</td>
</tr>
</tbody>
</table>

13. 2-way analysis of variance for spatial scores on tins and huts pictures (data in table 5.7)

<table>
<thead>
<tr>
<th>7-8 13-14 Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tins 5.9 6.2 8.0</td>
</tr>
<tr>
<td>Huts 7.1 7.3 8.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tins/Huts</td>
<td>12.1</td>
<td>1</td>
<td>12.1</td>
</tr>
<tr>
<td>Age</td>
<td>38.69</td>
<td>2</td>
<td>19.34</td>
</tr>
<tr>
<td>T/H x Age</td>
<td>6.2</td>
<td>2</td>
<td>3.1</td>
</tr>
<tr>
<td>Residual</td>
<td>217.467</td>
<td>84</td>
<td>2.58</td>
</tr>
<tr>
<td>Total</td>
<td>274.456</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chapter six

14. Four-way analysis of variance (data in Table 6.1).

<table>
<thead>
<tr>
<th>df</th>
<th>SS</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP</td>
<td>1</td>
<td>2.50</td>
<td>10.12</td>
</tr>
<tr>
<td>Age</td>
<td>2</td>
<td>8.13</td>
<td>16.45</td>
</tr>
<tr>
<td>MP x Age</td>
<td>2</td>
<td>0.10</td>
<td>0.21</td>
</tr>
<tr>
<td>Dim</td>
<td>1</td>
<td>13.95</td>
<td>56.44</td>
</tr>
<tr>
<td>Dim x MP</td>
<td>1</td>
<td>9.49</td>
<td>38.39</td>
</tr>
<tr>
<td>Dim x Age</td>
<td>2</td>
<td>1.69</td>
<td>3.41</td>
</tr>
<tr>
<td>Dim x MP x Age</td>
<td>2</td>
<td>0.22</td>
<td>0.45</td>
</tr>
<tr>
<td>S (Dim x MP x Age)</td>
<td>108</td>
<td>26.70</td>
<td>2.85</td>
</tr>
<tr>
<td>Angle</td>
<td>2</td>
<td>33.28</td>
<td>191.59</td>
</tr>
<tr>
<td>MP x Angle</td>
<td>2</td>
<td>3.71</td>
<td>21.39</td>
</tr>
<tr>
<td>Angle x Age</td>
<td>4</td>
<td>0.95</td>
<td>2.74</td>
</tr>
<tr>
<td>Dim x Angle</td>
<td>2</td>
<td>2.87</td>
<td>16.50</td>
</tr>
<tr>
<td>MP x Angle x Age</td>
<td>4</td>
<td>0.79</td>
<td>2.28</td>
</tr>
<tr>
<td>Dim x MP x Angle</td>
<td>2</td>
<td>3.92</td>
<td>22.60</td>
</tr>
<tr>
<td>Dim x Angle x Age</td>
<td>4</td>
<td>0.59</td>
<td>1.70</td>
</tr>
<tr>
<td>Dim x MP x Angle x Age</td>
<td>4</td>
<td>0.45</td>
<td>1.32</td>
</tr>
<tr>
<td>Error</td>
<td>216</td>
<td>18.75</td>
<td></td>
</tr>
</tbody>
</table>

246
15. Wilcoxon Rank Sum test.

Comparison of scores for 3 and 4 year olds under the 3D motion parallax present and absent conditions with the 70% viewing arrangement.

<table>
<thead>
<tr>
<th>MP present</th>
<th>Raw scores</th>
<th>Rank</th>
<th>MP absent</th>
<th>Raw scores</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.5</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>1</td>
<td>8.5</td>
<td>1</td>
<td>8.5</td>
</tr>
<tr>
<td>4</td>
<td>19.5</td>
<td>2</td>
<td>12.5</td>
<td>2</td>
<td>12.5</td>
</tr>
<tr>
<td>4</td>
<td>19.5</td>
<td>2</td>
<td>12.5</td>
<td>2</td>
<td>12.5</td>
</tr>
</tbody>
</table>

\[ S = 61.5 \]

For a one-tailed test, the limit of \( W \) at the .05 significance level is 83.

As the value of \( S \) is outside the limit, the difference between the treatments is significant.
APPENDIX C

An experiment designed to test the hypothesis that young Malawians were sensitive to horizon information in the Jahoda-McGurk test.

Introduction

Hagen and Jones (1978) criticised the black-and-white version of the Jahoda-McGurk test on the grounds that the pictures were generated without regard to the geometric rules of perspective. The picture of two adults, one pictorially more distant than the other, depicts a greater proportion of the rearground adult above the horizon, thus implying a taller rearground than foreground figure. The experiment to be reported here was designed to test for an influence of this information for a taller rearground figure by comparing accuracy of size responses to copies of the Jahoda-McGurk pictures with accuracy of size responses to a set of similar figures in which the horizon ratio information was corrected.

Materials

A set of eight pictures was constructed so as to be as similar as possible to the Jahoda-McGurk pictures. A second
set was then constructed in which the position of the rearground figure was altered so that equal proportions of the rearground and foreground adults were above and below the horizon. This adjustment resulted in less elevation of the rearground figure in the modified pictures. A set of four training pictures was also constructed with the figures in the foreground positions. Examples of the pictures are shown in figure 16.

Subjects

45 subjects were to be tested, 15 in Primary standard 2 who were aged 7-8 years, 15 in Primary standard 8 who were aged 13-14 years, and 15 University students, aged 19-20 years. Testing was to be conducted by the author and a male assistant who had helped collect data for previous portions of this research.

Procedure

Testing procedure was to be the same as used in experiment 7 (Chapter Five), and as used by Jahoda and McGurk. The pictures were to be displayed vertically to the subject, and a horizontal response board was to be placed on the table between the subject and the pictures. The subject would be given four dolls, two 'ladies' and two 'girls', the 'girls' being two-thirds the size of the 'ladies', and he
would be instructed to position the dolls on the response board in the positions he perceived them to be from the picture.

Scoring was to be the same as in experiment 7, with size and spatial responses being scored separately. The pictures were to be presented in a random order, with the proviso that the left-right reversals of a lady-girl arrangement did not follow one another. The set of uncorrected pictures were to be presented first in half the trials and the set of corrected pictures first in the other half, in each age group.

Results

The hypothesis that there was no significant difference between the means for the corrected and uncorrected sets of pictures would be tested. It was predicted that the hypothesis would be rejected, and that accuracy of size and spatial scores would be greater with the uncorrected than with the corrected pictures.
Figure 16a. Copy of picture from Jahoda and McGurk 1974c, showing an adult in the foreground and a child in the rearground.

b. Modified version of figure 16a.
Figure 16c. Jahoda-McGuirk version of two adults.

d. Modified version of two adults.
APPENDIX D

Table of results for Malawian subjects tested in experiment 9 and for American subjects tested by Yonas and Hagen (1973).

<table>
<thead>
<tr>
<th></th>
<th>3 and 4 years</th>
<th>7 and 8 years</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% 80% 70%</td>
<td>100% 80% 70%</td>
<td>100% 80% 70%</td>
</tr>
<tr>
<td>2DMP</td>
<td>65 15 10</td>
<td>78.8 17.5 12.5</td>
<td>95 67.5 32.5</td>
</tr>
<tr>
<td>( 82.5 35 25</td>
<td>80 35 12.5 97.5 87.5 32.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D</td>
<td>75 45 27.5</td>
<td>82.5 32.5 20 96 75 32.5</td>
<td></td>
</tr>
<tr>
<td>( 85 60 25</td>
<td>92.5 60 27.5 100 85 75 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D</td>
<td>72.5 52.5 12.5</td>
<td>95 72.5 17.5 99 88 15</td>
<td></td>
</tr>
<tr>
<td>( 92.5 87.5 25</td>
<td>100 95 87.5 100 100 97.5 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3DMP</td>
<td>91.3 81.3 65</td>
<td>95 97.5 96 96 95 98</td>
<td></td>
</tr>
<tr>
<td>( 100 100 72.5</td>
<td>97.5 95 87.5 100 100 100 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percentages of subjects giving the correct size response. Lines of figures in parentheses are from Yonas and Hagen 1973, and are for American subjects; lines of figures without parentheses are for Malawians.
APPENDIX E

Level of pictorial sophistication of subjects tested

The subjects in the rural samples had rather little exposure to pictures. There were few books in the villages, and no posters or placards, but most children would probably have seen photographs at some time. In the town there were some paintings on the walls of bars, and films were shown in the community centre, and there were also advertising posters. The schoolchildren would in addition have seen pictures in their schoolbooks. There was no television in Malawi.