INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.

2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.

4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.

5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

University Microfilms International
300 North Zeeb Road
Ann Arbor, Michigan 48106 USA
St. John's Road, Tyler's Green
High Wycombe, Bucks, England HP10 8HR

77-20,508

WU, Rosalind Jane, 1948-
DEVELOPMENTAL CHANGES IN PROCESSING
PICTURES OF COMMON OBJECTS.

City University of New York, Ph.D., 1977
Psychology, experimental

Xerox University Microfilms, Ann Arbor, Michigan 48106

DEVELOPMENTAL CHANGES IN PROCESSING PICTURES OF COMMON OBJECTS

by

ROSALIND WU

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1977

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

April 15, 1977
date

Joan S. Girgus
Chairman of Examining Committee

May 16, 1977
date

Florence L. Denmark
Executive Officer

Joan S Girgus

Gilbert Kaplan

G J Sorbman
Supervisory Committee

The City University of New York

ACKNOWLEDGEMENTS

I would like to express my appreciation to the principal, staff and students of P.S. 68 and P.S. 192 in New York City for their participation in these studies. Joyce Block, Lois Citron, Steve Cohen, Milka Colon, Marian Getzler, Bruce Kamiat, Eva Kerzner, Kathleen King, Leticia Maldonado, Selene Marrett, Kathleen Moody, Nancy Rotiroti, Carole Schaffer, David Smith, Lucille Spivak and Cynthia Weinman unselfishly offered their time to assist conducting the experiments.

I thank Dr. Louis Gerstman, Dr. Bernard Gorman and Dr. Gilbert Voyat for their advice on data analysis and for many stimulating theoretical discussions. Above all, I am indebted to my friend and advisor, Dr. Joan Girgus, for her patience and guidance in the preparation of this dissertation.

Abstract

DEVELOPMENTAL CHANGES IN PROCESSING PICTURES OF

COMMON OBJECTS

by

Rosalind Wu

Advisor: Professor Joan S. Girgus

A review of the theoretical literature on shape perception suggested that some features of an object in a drawing are more informative for recognition than other features. Developmental theorists have further hypothesized that the informativeness of a feature for recognition may change with age. Although recent studies of information processing have shown that judgments of information content in arbitrary divisions of pictures correlate with eye fixations and visual search in adult subjects, their relationship to actual recognition performance and its development has not been examined. The present studies were performed to explore the relationship between judged information content and recognition performance in adults and children.

Ten pictures of common objects (house, chair, tricycle, cap, scissors, fish, mitten, telephone, pocketbook, lamp) were each divided into 64 equal squares. The informativeness of the parts of the pictures for recognition was ranked by subjects of six, nine, twelve and twenty-two years in two pilot studies. The pictures were then presented in increasing levels of completeness to a different group of subjects for recognition. In Experiment 1, subjects aged seven, eleven and twenty-one years were given up to twenty parts of the pictures for recognition. One-half of the subjects received the twenty parts added according to the information rankings of the adult subjects in the pilot study, beginning with the part judged to contain the largest amount of information content, then progressing to pieces of lower and lower information rank in a systematic fashion. The other half of the subjects received the same twenty parts of the pictures added in random order. In Experiment 2, nine-year-olds and college students were tested on the same experimental paradigm as in Experiment 1. However, the parts of the pictures were added according to either adult rankings of information content or rankings by nine-year-olds in the pilot study.

The results indicated that in both experiments, the ease of recognition differed significantly from picture to picture. The number of parts needed for recognition also decreased with age and with earlier presentation of more informative pieces, as determined by judged information content. Information ratings by adult subjects were more effective in reducing the number of parts required for recognition than either ratings by nine-year-olds or by random additions of the twenty most informative pieces of the picture. The difference in recognition performance between adults and children increased for the difficult pictures, but not with different orderings of information cues.

From these results, the following conclusions were made concerning recognition of drawings of common objects: (1) Judgments of informativeness of arbitrary divisions of drawings by adults can provide a reasonably reliable measure of informativeness of the parts of pictures for recognition. (2) Informative cues for adults are also informative for children as young as seven years. (3) Judgments of informativeness by nine-year-olds, though less reliable as a measure of informativeness, nevertheless show that nine-year-olds are able to understand and categorize information. (4) By seven years, most children are able to utilize multiple cues for object recognition. (5) Age improvements in recognition performance can be attributed to differences in the utilization of informative cues.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

A number of theories about human information processing have been proposed in the past several decades. Most of these theories have been based on data from research with adult subjects. An increasing number of researchers have attempted to investigate some of the developmental implications of these theories and to assess the extent to which data from children's information processing verify the theories. Many developmental theorists (Wohlwill, 1960, 1962; Goodnow, 1972) have speculated that qualitative differences may exist between the information processing modes of adults and children. Wohlwill (1960) has suggested that children, as compared to adults, require more redundancy in information input and depend more on multiple cues in order to perceive a shape or pattern correctly. On the other hand, Piaget (1965) believes that children are often unable to deal with multiple cues and a child may experience difficulty with conservation tasks because he is unable to cope with too many features simultaneously. Goodnow (1972) has suggested that the child's information load, capacity and sequential constraints may differ from the adult's. She has shown that, when children process information, they often attend to items in the environment considered redundant by adults while ignoring properties considered critical by adults. It appears

that children may differ from adults in terms of the amount of information they are capable of processing, the way in which they deal with an information input and the type of organization they prefer to impose on incoming information. In other words, although children and adults often perform similarly on a large variety of tasks such as recognizing objects, reciting rhymes and singing songs, in order to obtain such performance from children, one may have to provide the child with multiple cues, different kinds of information input, or a different organization of the information.

Many investigations into the development of visual information processing have dealt with the use of redundant information. For example, Nelson (1972) showed that children's need for redundancy in identifying pictures differing in familiarity and ambiguity decreased from age 18 months to 24 months. Wohlwill (1962) discovered that although younger children may need more redundancy, they are actually less able to process redundant texture cues. Girgus (1973) also found that when subjects processed successively presented geometric shapes, only seven and nine year olds improved with repetition of the stimulus presentation. Five year olds could not take advantage of the additional viewing opportunities. These studies indicate that the use of redundant information content indeed differs with age. However, no one has yet tackled the basic issue of what information cues are actually utilized by

young children in visual information processing and whether those cues differ from the ones used by adults. This paper is concerned with the identity of the information cues used by children and adults during recognition of drawings of common objects. It is therefore appropriate to begin with a discussion of the use of information content in recognition.

Information content in drawings of common objects

It has been shown that young children generally experience little difficulty in identifying drawings of common objects, based on shape or pattern cues alone, and in the absence of context, size, color, or texture information (Hochberg & Brooks, 1962). This ability to recognize outline drawings implies the possession of information processing capacities in children. However, it is possible that the means by which children achieve recognition is often mediated by a small number of pictorial cues; that is, a drawing need not contain many elaborate details of an object in order to be correctly identified, and many different ways of depicting the same object may still produce correct identification. This suggests that object identification is made on the basis of some subset of the entire array of possible attributes. In fact, Hochberg (1972) has hypothesized that a good caricature may be more recognizable than a highly accurate drawing or a perfect photograph. This also

implies that not all pictorial representations are readily or equally recognizable and that an easily identifiable drawing does not contain arbitrary features. For instance, one often encounters difficulties deciphering the contents of a modern painting which does not contain the conventional set of attributes of the object being depicted, or arranges the set of attributes in an unorthodox manner. Thus, a drawing must contain a sufficient number of informative features and appropriate relationships between such features in order to be identified. A subject would be more likely to recognize a drawing of an object if the drawing includes features of the object that are informative for him than if the drawing contains few or none of these features. In other words, the more informative the features, the greater the probability of recognition given the presence of the features.

Goodnow's (1972) research has shown that when children translate a series of auditory taps into a series of visual symbols such as dots or numbers, they often ignore properties considered important by adults such as the length of intervals or the number of items in a series. On the other hand, the children included in their translations properties not considered critical by adults, such as the speed at which an item is written or the spatial location of taps. These data suggest that the cues attended to by children, and presumably those informative for them, may not be the crucial cues for adults. Perhaps there may be similar developmental differences in the informative cues for recognition of pictures of common objects.

Anecdotal observations by Piaget (1954) have provided some indication of the use of informative features for recognition by infants. Piaget reports that when his daughter Lucienne at 0;9 was presented with a cellulose stork, she attempted to grasp it when the animal's head or tail was visible; the sight of the animal's feet alone did not lead to attempts at grasping. These observations of Lucienne's behavior indicate that visual stimuli in everyday situations may be recognized on the basis of limited or incomplete information. More significantly, Lucienne's reactions reveal that some parts of the object are more salient than others for its recognition. How is it that the head and the tail of the stork are more informative than the feet? Are there general rules that allow us to predict which attributes will be more informative for recognition? Are the informative cues for Lucienne the same as those for other infants and for adults? The experiments described in this dissertation attempt to answer the last question -- whether features informative for recognition by children are the same as those informative for recognition by adults.

Theories of Form Perception

The problem of feature utilization in recognition is not unfamiliar in the study of shape perception. Indeed, many contemporary theories of form perception have tried to explicate the mechanisms by which objects are recognized on the basis of

various attributes of the objects. Although most of the theories are concerned primarily with adult perception, many of them have developmental implications and suggest possible differences between adults and children in cue utilization.

Hebb (1949) has proposed a theory of form perception in which perceptual recognition is the result of the neurological integration of stimulus attributes that were originally independent. Based on data from Von Senden, whose congenitally-blind patients followed corners of forms after they gained their sight, Hebb concludes that sequential visual-motor exploration of these features are basic to the development of form perception. When the eye focusses on a feature, cortical cells are activated. Repeated firings from repeated sequential fixations are assumed to lead to structural changes in the synaptic connections between the cells which are repeatedly fired in sequence, such that their stimulation thresholds for firing are drastically lowered. Eventually, these connected cells form cell assemblies that fire in reverberatory circuits whenever any one cell is stimulated. After more visual experience, the cell assemblies in different parts of the cortex become connected to each other into phase sequences which represent stored prototypes of the perceived forms. Finally, the phase sequences operate so that stimulation of several cells in a cell assembly through the fixation of a feature will set the entire phase sequence in motion. The successive rapid firing of the cells in a phase sequence permits form recognition.

According to this theory, different parts of the stimulus are not equivalent for its identification. The features that are fixated more often will activate cells within well-integrated cell assemblies and trigger off phase sequences more easily, with the result that recognition will be expedited. Recognition should be more difficult when one fixates on features that were less often fixated previously. Thus, Hebb predicts that the parts of a figure that have been fixated more often by the subject during visual exploration will be more informative for recognition. In addition, since the sequence of visual exploration affects the structure of phase sequences, the order in which features are fixated during recognition may affect the speed of recognition.

Brunswik (1954) has argued that perception must be both probabilistic in nature and characterized by multiple cue usage. For example, a retinal image of convergent lines often indicates parallel lines receding into space in a picture of a city, but the same retinal image may not be an indicator of parallelism and depth in a picture of a jungle. In Brunswik's words, convergent lines have less "ecological validity" as a depth cue in the latter instance. Through repeated experience of convergent lines in conjunction with the experience of depth, a city dweller may be more likely than a jungle inhabitant to associate the two occurrences and utilize convergent lines as a depth cue. Moreover, since linear perspective is not an absolute indicator of depth,

observers are also forced to learn to make use of multiple cues and mutually substitutable cues such as familiar size or textural cues, in order to increase perceptual veridicality.

Based on Brunswik's theory, pictorial cues of high ecological validity within an object, i.e. those with a high probability of occurrence in the object, would be the informative parts of the object for recognition. In addition, the informativeness of any cue is expected to increase with increased experience with that cue, so that the informativeness of any cue presumably increases with the age of the perceiver. Further, flexibility in cue utilization and the ability to process multiple cues during recognition is also expected to increase with age. Familiar or highly probable combinations of cues would also increase the likelihood of correct recognition, especially among adult subjects.

Other theorists also espouse a constructive view of form recognition, though their speculations are more cognitive and less physiological than Hebb's and less stimulus-oriented than Brunswik's. For example, Hochberg (1968) has introduced the schematic map to explain how the presentation of pictorial attributes might lead to recognition.

The schematic map is a program of stored expectancies built up from exploratory eye movements. It is a set of rules indicating to the perceiver where to look and what to expect. During recognition, features of the objects, sampled from successive glimpses, are matched up with the most likely schematic map, which provides expectancies as to what will be seen during further sampling.

Identification occurs when further sampling confirms these expectancies. Therefore, provided that the available features enable access to the correct schematic map, or to disconfirmation of the wrong schematic maps, the organism is able to identify the object. The theory also predicts that when a perceiver is using the wrong schematic map, or has an inefficient schematic map which fails to disconfirm contradictions between the sampled features, erroneous identification may result even when all the cues are available to him.

Schematic maps are not detailed images of the object, and do not contain all the features of the object, so that correct identifications are not equally likely from sampling different features. Only those features in the drawing that are also contained in the organism's schematic map would lead to correct identification. Hochberg maintains that perceptual development is a result of changes in the content of schematic maps, and not of structural changes in the nervous system, as Hebb (1949) has hypothesized. Changes in the structure of a schematic map would consist of changes in the specification of what one would expect to find as a function of various fixation patterns. Hochberg hints that the probability and ease of recognition might improve with repeated visual exploration insofar as this leads to the storage of new features and the build up of more efficient schematic maps. Hence, recognition performance should improve with age and amount of previous visual exploration.

The features that have been explored more often in the past are more likely to be contained in the schematic map, and these features would be more informative for recognition.

Neisser's (1967) analysis-by-synthesis process of perceptual recognition bears a marked resemblance to Hochberg's (1968) theory of schematic maps. Recognition is seen as a twostage constructive process mediated by feature analyzers and based on both the present context and past experience. Neisser believes that features are the basic units of recognition, but postulates no invariant basic features. Rather, the nature and the size of the feature is a function of the task, the context, and the expertise and experience of the perceiver. In the initial preattentive stage, Neisser describes a global, wholistic process which assesses environmental context and stimulation in a crude parallel fashion and then directs the organism's attention to features of interest. In the second, more analytic stage, the previously selected features receive "focal attention" sequentially; that is, the features are analyzed and synthesized into a meaningful concept using other incoming information and stored information from past experience. The processes of focal attention are controlled by a system analogous to an executive routine in a computer program, which has the capability of making changes in its own operations through learning. Unfortunately, Neisser has been less specific concerning developmental changes in the executive routine than Hochberg (1968) has been concerning schematic

maps. Nevertheless, it is possible to predict that informative features for recognition are probably those chosen for closer examination by preattentive processes, and since the nature of these features vary according to the experience of the subject, the theory also predicts age differences in the size and identity of the salient features utilized in recognition.

Piaget's (1968) theory of reconstructive recognition is based on internal representations called schemas, which are actual memory images rather than a series of expectancies or probabilities as in the theories of Hochberg (1968), Neisser (1967), and Brunswik (1954). Piaget differentiates between three memory processes: recognition, reconstruction, and evocation. In the first two years of life, objects are identified from visible cues using what Piaget calls recognition. During this time, the infant merely responds to various cues from the object based on situational contexts. By 1½ or 2 years of age, the child possesses symbolic representations of objects which may be either mental images or linguistic codes. These symbolic representations, or schemas, constructed by the child through interactions with and imitation of the environment, allows him to recall or reproduce objects that he had previously encountered, using what Piaget calls evocation.

Intermediate between recognition and evocation is a type of memory that Piaget calls reconstruction, in which the observer is given certain elements of the object and asked

to reproduce the original configuration or identify what he sees. This situation is similar to one in which the child is asked to identify a picture of an object which only contains some of the informative features of the object. During reconstruction, a mixture of recognitory and evocative processes are employed: the perceiver actively reorganizes the available pictorial cues, which, combined with gapfilling and inference, leads to the evocation of a mental image. Then the features of the picture are matched with the features of the mental image. Identification follows from a satisfactory match.

The attention paid to the various features of an object plays an important role in the construction of schemas and in the reconstructive process. Piaget believes that young children up to about age seven tend to be attracted to certain prominent features in an object and center their attention on these features to the expense of others during construction or reconstruction. He has not indicated specifically what types of features are centrated, but he would probably predict that the features most often encountered and centrated during the construction of a mental representation would be most informative for recognition. However, these features may not be the same ones centrated in the process of reconstruction, so that a child may sometimes fail to match his internal representation with his perceptions and therefore fail to recognize a familiar object.

In sharp contrast with the foregoing theories emphasizing progressive integration of features during recognition and during the development of recognitory ability with increasing age, Gibson(1969) has proposed a theory of perceptual recognition based on progressive differentiation of features. Rather than going beyond the information given, recognition consists of extracting invariant features of an object from the stimulus. Gibson argues that objects are bundles of features that a child gradually learns to discriminate from other bundles of distinctive features. The differentiated features are subsequently organized hierarchically and the child learns which groups of features are invariant for a particular object and which groups of features distinguish the object from other objects. Through learning, the child attends to some critical variables and ignores others. Gibson argues that initial identification of an object in a drawing by a very young child is based on global and undifferentiated characteristics of the object, implying that when the object is unfamiliar, its identification is virtually impossible in the absence of the entire object. Gradually, as more and more distinctive features of the object are differentiated, identification might be possible from a relatively small number of pictorial cues,provided that the available cues are the ones that have been differentiated. Thus the informative cues for recognition are the differentiated cues. In order for an

observer to recognize an object in a drawing, it is important that the drawing contain those differentiated cues. Adults have differentiated more features of objects, so that many different combinations of cues are equally likely to lead to correct identification. Gibson rejects the notion that recognition is an inferential process in which children require more redundancy due to the primitive nature of their strategies for perceiving. She maintains that a child does not really need more information than an adult in order to identify an object, but the child needs special kinds of information. He may experience greater difficulty during recognition when only a small number of cues are available because he has not differentiated the features provided. If the differentiated cues were available, the child would not require any surplus information. In fact, according to Gibson, the child may be less aware of redundancies in pictures because he has not yet learned to distinguish one feature from the other.

While Gibson has eloquently described the results of differentiation, she has given us less insight into the mechanisms behind differentiation, which she has described as abstraction, filtering and exploratory activity. These activities are presumably motivated by cognitive factors such as reduction of uncertainty and an intrinsic drive for knowledge. However, it is unclear exactly how exploratory behavior leads to differentiation.

It may be a fair assumption that the pictorial cues that are encountered more often during visual exploration would be more differentiated and thus are more informative for the recognition of the object.

The major developmental theories of form perception summarized thus far have provided a variety of explanations as to how some parts of a drawing may contain more information for recognition than other parts. These differences in informativeness have been attributed to the child's exploratory eye movements, probability learning, the nature of the internal representation of the objects and the differentiation of one feature from another. It appears that differential attention to different parts of pictures by the child play a major role in the formation of Hebb's phase sequences, Hochberg's schematic maps, Piaget's schemas and in determining which features receive focal attention or are differentiated in Neisser's and Gibson's theories respectively. However, apart from Hebb, who believes that corners are the basic features fixated, the various theorists have not been explicit concerning the nature of the basic features attended to during visual exploration, and generalizations regarding the identity of the informative features must await empirical discovery.

Although research attempts to explore the theoretical issues concerning the identification of informative features, their relationship to visual attention and especially their developmental aspects have been far from systematic, three separate areas of study have shed some light on them. Research in the first area examines stimulus factors affecting developmental changes in object discrimination or recognition. The second area of study involves the search for basic units of information content in visual perception, and the third area focusses on discovering the identity of the features fixated during normal visual exploration of an object, on the assumption that distribution of visual fixations will enable us to determine the basic units of visual information content.

Developmental Studies of Form Perception

A number of studies on the development of form perception have sought to discover the identity of the informative features for form recognition in children through stimulus manipulation. Gibson, Gibson, Pick & Osser (1962) have attempted to identify sets of distinctive features that must be differentiated in order to distinguish between the letters of the alphabet. Their research has contributed extensively to our knowledge of the specific features that children of various ages are

able to utilize in distinguishing one object from another. However, the features that they have identified are limited to the perception of uppercase letters or letterlike forms. This renders generalization of the features to other kinds of objects somewhat difficult. Furthermore, while the discovery of such dimensions of differentiation enables the child to judge if two objects are identical or not, it may not be sufficient for him to identify the objects. For these reasons, we must turn to research that deals more specifically with object identification, although such investigations have not manipulated the stimulus features as precisely.

The informative features for recognition of a drawing can also be identified by manipulating the number or type of features presented in the drawing and testing for ease of identification. Vurpillot & Brault (1959, cited in Gibson, 1969) attempted to determine the effect of the number of features presented in a photograph on judgments of the photograph. Familiar objects such as houses and dolls were presented to subjects, aged five through nine, in a variety of orientations. Subsequently, the subjects chose the photograph judged to be most like the object from among eight photographs showing the objects at different orientations and revealing different numbers of features of the objects. It was found that the children's choices were based on certain consistent features for each object

and that the number of features attended to increased with the child's age. However, the identity of a feature was not defined and a general rule for discovering informative features cannot be obtained from these data.

A third technique used to identify the informative features for recognition of drawings by children uses pictures of incomplete objects that contain varying amounts and types of pictorial cues. Correct identification of the incomplete drawings should then be a function of the informativeness of the features presented. Developmental research in form recognition with partial cues began early in the century. Wohlwill (1960) has reported two such studies by van der Torren (1907) and Schober & Schober (1919).

Van der Torren (1907) presented children with drawings of familiar objects at progressively increasing levels of completeness. On every trial, the subjects were required to identify the object and indicate which part of the object had just been added. He found that children needed more parts in order to identify the object, yet the ability to point out the part of the picture that was added with every new trial was almost perfect from age four.

Schober & Schober (1919) performed a similar study with one difference the complete outline of the object to be identified

was always visible, and more internal details were added on every trial. Under these circumstances, the presence of the outline of the object interfered with the four year old's ability to point out which internal detail had just been added.

More recently, a series of studies by Gollin (1962, 1965) also indicated that the number of parts required for correct recognition of incomplete drawings of common objects decreased with age when the parts were added one at a time.

A recognition study by Potter (1966) manipulated the clarity of the features rather than the features themselves. She examined the process of recognition in children by defocussing photographs into a blur and slowly bringing them into focus. As the photographs were brought into focus, subjects aged four through college age were asked to describe the pictures and to guess what the whole picture was about. Again, speed of recognition improved with age. Based on the subjects' verbal responses, Potter also observed that while young children shifted their attention unsystematically from one part of the picture to another with successive views, older subjects appeared to make increasing attempts to integrate the information gained from successive views.

These studies have shown that the amount of information and the clarity of the information needed for recognition differs with age. It appears that the organization and concentration

of the information in certain parts of the picture has a powerful effect on the child's ability to identify the object in the pictures, as shown in Schober & Schober's (1919) study. The study by Potter (1966) has also indicated that selective attention given the different parts of the pictures may be an important factor in recognition, as many theorists have predicted.

While these studies emphasize the differential importance of features for recognition, they have not clearly specified what kinds of information are important for recognition, nor have they controlled for the particular features being presented. The only developmental study that has systematically manipulated the features being presented for recognition was performed by Goldstein & Mackenberg (1966). Goldstein & Mackenberg showed that the ability to recognize a face, given only a part of the face, increased with the age of the subject and with increases in the visible amount of the face. Moreover, the feature that enhanced recognition the most for all age groups was found to be the region around the hairline. However, this study deals with the recognition of a very special class of stimuli and therefore provides us with little insight into the recognition of objects in general.

Progress in such research has largely been hampered by the lack of a good metric for visual form. Since we do not know a priori the appropriate unit of information, it is difficult to specify and manipulate the stimulus domain to discover the relevant information input necessary for recognition of everyday objects. The study of the psychophysics of visual form has been conducted primarily by non-developmentalists. An examination of their work may provide insight into how stimulus information might be manipulated in developmental studies of form perception.

The Search for Units of Information Content

One of the first psychologists who tried to quantify visual information content was Attneave (1954). By asking subjects to choose the parts of outline drawings that would facilitate the reproduction of the figures, Attneave demonstrated that the information in simple outline forms is concentrated in the points of maximum curvature. In order to verify his findings, Attneave developed a metric for producing geometric forms whose properties could be quantified precisely. Most researchers since Attneave have continued to use computer generated or "random" polygons or histoforms in their studies and have neglected the problem of everyday objects. For example, Brown & Owen (1967) used the computer to generate two-dimensional polygons according to specific rules. They then asked subjects to

classify the forms according to similarity. Factor analyses performed on these data indicate that compactness, jaggedness, skewedness and the placement of the dominant axis were prime determinants of the subjects' classifications.

Developmental research using the polygons generated by Brown & Owen (1967) has been done by Aiken & Williams (1975). Their subjects' classifications of similarity of these forms revealed that even children as young as eight years consistently utilized multiple dimensions. The number of features utilized and the importance of each feature in determining their classifications also increased with age. However, these two studies shed little light on the problem of specifying stimulus information in everyday objects, nor do they tell us anything about recognition of these objects. Some recent attempts have tried to overcome this neglect of the stimulus properties of pictures of real life scenes and objects.

Mackworth & Morandi (1967) have taken a photograph of a pair of eyes and another of a map of England and divided each picture into 64 squares. They asked one group of subjects to judge the recognizability of each of the 64 parts on a 10 point scale. Another group of subjects viewed each picture freely while their visual fixations for the various parts of the pictures were recorded. Both measures gave high readings for "unusual details and unpredictable contours", which, unfortunately, were not clearly defined in their paper.

Pollack & Spence (1968) have also used real pictures to relate information content to recognition and other perceptual tasks. In their study, five colored photographs from popular magazines were each subdivided into 70 parts. Subjects rated each part of the picture on a twelve point scale in answer to the question "To what extent would the information of the picture be altered if we removed the individual piece from the picture?" Subsequently, a second group of subjects was shown one part of a picture and asked to find that piece within the entire array of 70 parts. Error rates and search times were lowest for the segments with the highest rated apparent information.

The studies by Mackworth & Morandi (1967) and Pollack & Spence (1968) suggest that judgments of arbitrary divisions of pictures given in terms of their importance for recognition may provide a useful unit of measurement for information content. Once information content is successfully quantified, it can be manipulated to investigate the type of information input required for recognizing common objects in subjects of different ages.

Additional evidence that such judgments of information content may be the key to the discovery of informative areas for recognition of pictures are provided by studies relating judgments of information content to exploratory eye movements, which have been suggested by a number of theories to be the source of the differences in informativeness of pictorial features.

Studies of Eye Movement Patterns

Eye movement recordings from adult subjects (Zusne & Michels, 1964; Yarbus, 1967; Noton & Stark, 1971) have demonstrated that subjects do tend to fixate some parts of pictures more than others, in a systematic fashion. Loftus (1972) has related these systematic scanning patterns to recognition of pictures in adult subjects, by recording subjects' eye movements while they studied pictures to determine whether those pictures had been presented previously. The subjects' recognition performance was found to be a positive function of the number of fixations on the pictures, but independent of exposure time. Loftus's data can be predicted from the recognition theories of Hebb (1949) and Hochberg (1968). In Hebb's interpretation, the larger the number of visual fixations, the stronger the likelihood of activating the entire phase sequence that would lead to recognition. In Hochberg's theory, increases in the number of visual fixations would enable the subject to test out more of the expectancies prescribed by his schematic maps, so the likelihood of rejecting a false schematic map and discovering a correct schematic map would increase, leading to better recognition performance.

Age differences in scanning patterns have been explored by Fantz (1963), Salapatek & Kessen (1966), Kessen (1967),

Salapatek (1968) and Mackworth & Bruner (1970). The data from Fantz, Salapatek and Kessen have all shown that the infant's eye movements become more extensive and efficient with increasing age while they scan simple geometric forms. Mackworth & Bruner (1970) found that the eye tracks of six year olds averaged only two-thirds the length of adult tracks and that the children had twice as many very small eye movements when scanning photographs of scenes and objects.

Similar scanning patterns have been found in children while they are performing a variety of perceptualcognitive tasks. Vurpillot (1968) asked children to determine whether pairs of pictures were identical. The eye movements that she recorded while subjects were examining the stimuli showed that the responses of "same" or "different" by children of five or six years were not based on thorough scanning of the stimuli. Olson (1970) has asked children to examine a stimulus pattern in order to reproduce it later. He found that children did not systematically search the stimulus in order to remember it, but restricted their gazes to small areas.

The research on scanning patterns has generally indicated that visualmotor exploratory activity becomes, with age, more extensive, more precise and more systematic. However, these studies have concentrated more on describing the nature of the eye movements than on the nature of the features fixated. In Gibson's (1969) view, the features receiving more attention

during visual exploration are more likely to be the differentiated ones utilized for picture comparisons and recognition. In support of her theory, Nodine & Steuerle (1973) and Nodine & Simmons (1974) found that third graders fixated proportionately more distinctive features than kindergartners when comparing graphemes and letterlike symbols. However, from their studies, it is unclear whether the difference in number of fixations was the cause or result of differentiation.

Two important studies have tried to relate scanning patterns more precisely to judgments of information content of the stimuli. Baker & Loeb (1973) tested whether the same physical elements which predict judgments of stimulus importance also receive more visual attention. They arbitrarily divided polygons and histoforms into nine parts, and obtained subject's ratings of importance for each part. It should be noted that their published report gives no definition of importance, so it is unclear whether importance for recognition is intended on the part of the subjects making these judgments. For each part of the picture, Baker & Loeb also measured the frequency and duration of eye fixations when subjects were asked to view the entire stimulus freely. The duration of fixation for each part correlated highly with its reported importance as well as with high information content as defined by Attneave (1954).

Mackworth & Bruner (1970) performed a similar study using a picture of a fire hydrant cut up into 80 squares. Adult subjects unfamiliar with the complete picture rated each square for informativeness on a ten point scale. Informativeness was defined in terms of the extent to which the subject believed he could pick out the square again on a second trial. Eye fixation patterns of the complete picture were obtained from a second group of adults and six year olds while they attempted to recognize the picture as it was gradually brought into focus from a blur in six successive ten-second presentations. The adults' fixations tended to concentrate on the same areas of high informativeness as rated by other adult subjects. The children tended to focus their attention on less informative areas and different children concentrated their gazes on different areas of the picture. These age effects were more marked for the blurred displays than for the focussed pictures.

The studies by Baker & Loeb (1973) and Mackworth & Bruner (1970) suggest that judged information content is related to visual fixations and since visual fixations have been hypothesized by various theorists (Hebb, 1949; Hochberg, 1968; Piaget, 1969; Gibson, 1969) to play a role in the development of differences in informativeness of stimulus cues, it appears that judged information content may allow us to test the differences between these theories of form recognition in an indirect manner. However, previous ratings of information content suffer from

two problems. First, they did not deal directly with the informativeness of the parts of the pictures for recognition of the entire picture. Secondly, Mackworth & Bruner (1970) have suggested that children's fixations correlated less well with judged information content obtained from adults than did adult fixations, suggesting that the importance of various features for recognition may be different for adults and children. Thus, for developmental studies of shape perception, it would be necessary to obtain judgments of information content from children. Two pilot studies were performed to remedy these shortcomings. They obtained ratings of information content specifically designed to assess the informativeness of the parts of pictures of common objects for recognition and explored whether the judgments of information content change with age. Since neither study is published, they will be described in detail in the following pages.

CHAPTER TWO

THE PILOT STUDIES

The First Pilot Study

Twenty-five line drawings of common objects culled from children's coloring books were used for the first pilot study. A grid of 64 squares was superimposed on each of the drawings so that between 28 and 37 squares contained some part of the object. Twenty-three college students were asked to rank the parts of the picture for information content in the following manner: for each drawing, the subject first chose the square in the grid which he would show another person to help him guess what the whole picture was, if only one square in the grid could be seen. The subject then indicated the square that would be the next most helpful, assuming that the initially chosen piece remained in view. This procedure was continued until 20 squares had been chosen from the picture, in order of their importance for recognition.

To determine the amount of agreement in the subjects' rankings, Kendall's coefficient of concordance (W) was computed for every picture. The mean W was .45 with a range from .27 to .53. When W was converted to RHO for all possible pairs of subjects, 16 out of the 25 average correlations were significant beyond the .05 level. This indicates that, for most pictures,

subjects agreed to some extent about which parts of common objects are more important for recognition.

A Spearman's RHO correlation of -.52 was found between W for the 25 pictures and the number of squares covered by the picture, indicating that the amount of agreement between subjects increased as the picture covered a smaller and smaller area in the eight-by-eight grid.

The Second Pilot Study

The stimuli used in this study were chosen from the 25 used in the previous study according to several criteria:

1. All pictures must be easily recognized and named by young children. Ten kindergarten children from a public school were asked to name the 25 pictures. Any picture that could not be named by all subjects was eliminated from this study.
2. Since the subjects' agreement as to information ranking is affected by the area occupied by the picture, the pictures chosen must have approximately the same number of squares carrying some part of the picture.
3. These pictures should yield a level of agreement between the subjects in the first study that was significant beyond the .05 level. This would allow us to ascertain if subjects of different ages utilize similar strategies and criteria in ranking parts of pictures for information content.

Based on these criteria, ten out of the original pool of 25 pictures were included in the second study. The pictures were house, chair, cap, tricycle, scissors, fish, telephone, lamp, mitten and pocketbook. The pictures covered 32 to 35 squares in the 8 by 8 grid with adult subjects' ranking agreements ranging from .45 to .51 as measured by Kendall's W in the first pilot study. Copies of the ten pictures are included in the appendix to this paper.

For each of the ten pictures, white drawing paper was first glued onto a piece of 1/8 inch plexiglass and then cut into 64 one and one-half inch squares. These squares were then arranged into an 8 by 8 matrix and the pictures were drawn on the squares with black permanent marker. A small magnet was glued onto the back of each plexiglass square so that it would adhere to a steel sheet and would not be easily moved out of place.

Fifteen subjects in each of four age groups participated in the study -five year olds, eight year olds, eleven year olds and college students. Prior to participation in the experiment, each subject was required to name each of the ten stimulus objects.

After naming the ten objects, the subjects worked with the pictures one at a time in random order. Each picture puzzle was presented to the subject on a steel sheet with a copy of the picture between the puzzle and the steel so that when a

piece of the puzzle was removed, the entire picture was still visible. The following instructions were given to each subject:

> "Supposing you are playing a game with your friend. Your friend cannot see this picture and you want him to be able to guess what it is. You cannot talk to your friend, but you can show him one piece of the picture to help him guess what the whole picture is. Which piece do you think would help him guess right?"

After the subject chose a piece of the picture, his choice was placed on a second steel sheet in its proper orientation and location. Then the experimenter said:

> "This is what your friend would see. Suppose he cannot guess what the whole picture is, which piece would you add over here for him to see do that he can guess what the whole picture is? Try and make this side look as much like the whole picture as you can, so that your friend will guess right."

The second part of the instructions was repeated until the subject had chosen 20 parts of the picture. Whenever the subject chose a piece of the picture, it was placed on the second steel sheet in its appropriate relationship to the previous choices so that the subject could visualize what the guesser could see. The experimenter was careful at all times not to show approval or disapproval of the subject's choice. The experimenter also made sure that the subject looked at his latest choice in isolation and in combination with the previous choices before continuing to the next part.

Several analyses were performed on the data. The first analysis examined whether the amount of agreement among subjects

changes with age. Table 1 shows the amount of agreement among subjects of the four age groups as to the rank of each piece of the picture, using Kendall's W. The coefficients for adult subjects using the new procedure are comparable to the ones obtained from Pilot Study 1. However, only the coefficients for the pictures of the scissors and the cap achieved significance beyond the .05 level, probably because of the smaller number of subjects in this pilot study.

The coefficients of concordance shown in Table 1 seem to suggest that the amount of agreement among subjects increased with age. Two different explanations may account for this finding.

First, if these choices indeed represent the subjects' conception of information content, one can account for the age increases in concordance in terms of increases in agreement about which features are the most informative for recognition. Gibson, Gibson, Pick & Osser (1962) examined response latencies and confusion errors in matching letterlike symbols. Four year old children had the shortest latencies and fewest confusion errors for features such as size and closure, with 90° rotations providing intermediate difficulty, and mirror images and perspective transformations leading to the longest latencies and the most errors. Improvements in discriminative ability with age occurred first for the easiest transformations and much more slowly for the difficult ones. The consistent age trends indicate

Table 1

Kendall's Coefficients of Concordance

Pilot Study 2

Name of Picture	Kindergarten	3rd Grade	6th Grade	Adults
House	.30	.35	.39	.41
Chair	.17	.34	.35	.42
Pocketbook	.28	.32	.33	.42
Telephone	.28	.37	.35	.42
Fish	.25	.34	.33	.44
Lamp	.23	.37	.34	.44
Mitten	.20	.43	.34	.45
Bicycle	.25	.32	.35	.45
Scissors	.31	.33	.39	.49[a]
Cap	.21	.35	.35	.54[a]

[a] $p < .05$

that children tend to differentiate features in letterlike symbols in some specific order. If the same is true of differentiation of pictorial features, it would be expected that as more features of the pictures become differentiated, they would tend to be the same features, and greater concordance would be evident in the children's rankings of information content with increasing age.

On the other hand, it is possible that children of all ages actually utilize the same types of information cues for recognition, but the younger children have no awareness of which parts they actually use for recognition. Thus they choose parts of the pictures haphazardly in response to the instructions. This unsystematic selection would result in low coefficients of concordance for the younger children. The older children may be more aware of the types of cues that they employ for recognition, so their choices may reflect their cue utilization more closely. This increasing awareness of one's cognitive operations with age would lead to increases in concordance of choices with increasing age.

A second analysis of the data from the second pilot study investigated whether children actually use the same patterns of choices as adults do when ranking information content. Separate median information ranks were obtained for each age group for each square in each picture. The squares in each picture were then arranged in rank order to represent the average

order of choice for each age group. Figure 1 shows the results of the ranking procedure for one of the pictures. The numbers in each square are the median ranks for that square for the age group. Visual examination of such pictures revealed little difference between the median ranks of the two older groups of subjects; that is, the areas judged to be most informative by adults were also judged to be most informative by sixth graders. However, the younger groups' choices often differed from adult choices in the areas chosen as the most informative. In addition, successive choices made by six year olds seemed more frequently to be adjacent to each other than successive choices made by adults.

In order to test whether adults and children differed in the spatial distribution of their choices of ranked information content, the distance separating successive choices was examined in relation to age. The distance between any given choice and the immediately preceding one was measured using the following formula:

$$\Delta d = \sqrt{\Delta X^2 + \Delta Y^2}$$

where Δd is the distance between the two choices, and ΔX and ΔY are the respective horizontal and vertical displacements between successive choices given in number of squares. Thus, if the preceding choice is an adjacent square, either in a horizontal or vertical direction, then $\Delta d = 1$, and if the preceding choice is the next square along the diagonal, $\Delta d = 1.41$.

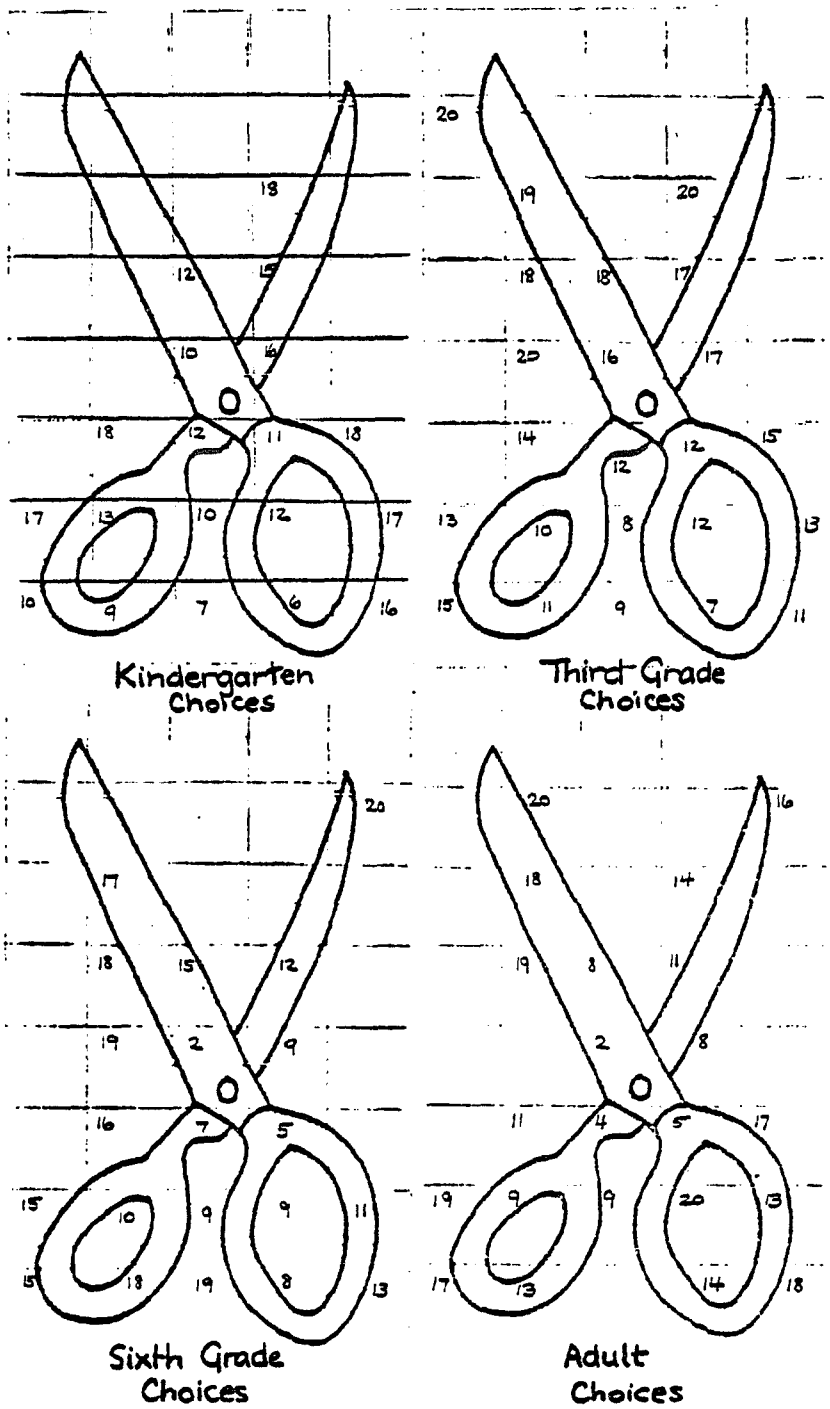


Figure 1. Median Information Ranks for the picture of the Scissors

Table 2 shows the mean distances between successive choices for each picture and each age group. A 4 x 8 analysis of variance performed on these data is summarized in Table 3. It shows that the mean distance separating successive choices differs from picture to picture and increases significantly with age. Specifically, the adult and sixth grade subjects make more long leaps in their choices as compared to the kindergarten and third grade subjects. These findings indicate that young children have a tendency to make successive choices on an adjacent or nearby square rather than jump to a square farther away.

The age differences in the physical distance separating successive selections of picture pieces match the description of children's scanning patterns given by Mackworth & Bruner (1970) who found that adults had more leaping eye movements covering distances greater than 6^{0} of visual angle than six year olds. The similarity in findings again strongly suggests that choices of information content reflect the subjects' exploratory eye movements or vice versa, for children as well as for adult subjects. Thus, judgments of information content may be an alternative to making eye movement recordings to test the assumptions of various theories of form recognition.

The first pilot study has shown that it is possible to obtain reasonably reliable judgments of information content from adult subjects. In the second pilot study, a technique was developed to obtain similar judgments from children, along

Table 2

Mean Distances between Successive Choices of Information Rank

Pilot Study 2

Name of Picture	Kindergarten	3rd Grade	6th Grade	Adults
House	1.68	1.78	1.95	2.09
Chair	1.77	1.80	1.96	1.76
Bike	1.62	1.64	1.75	1.67
Cap	1.52	1.76	1.84	2.01
Scissors	1.61	1.75	2.15	2.11
Fish	1.82	1.62	1.92	1.75
Mitten	1.70	1.92	2.09	1.86
Phone	1.49	1.58	1.85	1.84
Pocketbook	1.68	1.69	2.07	1.98
Lamp	1.61	1.72	2.23	2.12

Table 3

Summary Table of 4 x 10 Analysis of Variance

Pilot Study 2

Source	SS	df	MS	F
Between Ss	83.90	59		
Age	10.98	3	3.66	2.81*
subj. within grps	72.92	56	1.30	
Within Ss	86.64	540		
Pictures	4.15	9	0.46	3.26**
Age x Pictures	5.35	27	0.20	1.40
Pictures x subj.w.grps	71.14	504	0.14	
Total	164.54	599		

* $p < .05$

** $p < .01$

with some indication that these judgments also resemble the eye movement patterns of children. However, it remains unclear whether judged information content is a good predictor of actual recognition performance and thus provides a possible explanation for improvements in recognition performance with age.

In this dissertation, two experiments on recognition of incomplete pictures are presented. In each experiment, the type and order of information input was manipulated to study the effect on recognition. Experiment 1 investigates the extent to which information ratings by adult subjects in the pilot studies predict actual recognition performance in adults and children. Experiment 2 compares the efficiency of the information ratings of adults and children in predicting actual recognition performance.

CHAPTER THREE

EXPERIMENT ONE

A review of the experimental literature has shown that some parts of drawings carry more information for recognition than others (Attneave, 1954; Goldstein & Mackenberg, 1966). According to theories of shape perception, some features of an object in a drawing are more informative for recognition than others because they are more likely to:

1. activate an entire phase sequence (Hebb, 1949).
2. have higher probabilities of occurrence in the object (Brunswik, 1954).
3. have been incorporated into a schematic map (Hochberg, 1968).
4. be a part of an executive routine controlling analysis-by-synthesis (Neisser, 1967).
5. be present in the organism's schema of the object (Piaget, 1968).

or

6. be familiar distinctive features already differentiated by the organism (Gibson, 1969).

Various developmental studies (van der Torren, 1907; Schober & Schober, 1919; Gollin, 1965; Goldstein & Mackenberg, 1966) have also established that recognition of incomplete pictures improves with age. These developmental improvements may be attributed

to the fact that most of the drawings used in these studies presented pictorial cues informative for adults, but not for children, who might have found other sets of cues more informative for them. Theoretical speculation has generally supported the hypothesis that the informative cues for children may not be the same as the ones informative for adults.

In the views of Brunswik (1954) and Gibson (1969), every environmental cue carries a potentially specifiable amount of information depending on its frequency of occurrence or its usefulness in differentiating between classes of objects. Since both theorists believe that knowledge of probabilities of occurrence and utilization of the distinctiveness of a feature must be learned, they would predict performance to improve with age, when adults and children are given the same pictorial cues for recognition. Gibson (1969) has stated specifically that only the differentiated cues can be utilized for recognition, and since feature differentiation occurs in a specific age-related sequence (Gibson, Gibson, Pick & Osser, 1962), the informativeness of a particular cue is similar for subjects of the same age, but changes with age through differentiation.

Hochberg (1968) and Neisser (1967) have postulated more elaborate cognitive mediators between stimulus and percept. Thus, although environmental factors provide the initial input in the informativeness of a feature, cognitive mechanisms play a more prominent role in reorganizing and restructuring the

incoming information into schematic maps and programs of action that result in developmental differences in perception. Since a feature must be incorporated into the perceiver's cognitive representation in order to be informative, and both theorists have suggested that the size, number and organization of features in the internal representation change with age, it follows that adults and children may not share the same informative features for recognition.

According to Piaget (1968, 1969), in addition to differences in cognitive representations, differences in the process of reconstruction also predict age changes in the identity of informative cues. Regarding internal representations, he states that the nature and organization of a child's schema for an object may change with age according to his level of cognitive operation, even in the absence of new information input concerning the object, so it is possible that features informative at one level of functioning may not remain informative at the next.

Although the notion that the informativeness of a feature might change with age meets with theoretical approval, it has not been directly tested for lack of a precise quantification of informativeness or judgments of the importance of the various features of pictures. Judgments of information content contained in arbitrary divisions of pictures have been suggested by Mackworth & Morandi (1967) and Pollack & Spence (1968) as a method of determining the informativeness of pictorial information for

recognition. Such a measure appears theoretically satisfactory since judgments of informativeness have been linked to eye movement patterns (Baker & Loeb, 1973; Mackworth & Bruner, 1970), which have been repeatedly hypothesized to perform an essential role in determining the informativeness of visual cues for shape perception (Hebb, 1949; Hochberg, 1968; Piaget, 1969).

In the first study, the following predictions concerning cue utilization during recognition of drawings will be tested, using judgments of information content from adult subjects in the second pilot study:

1. If the informativeness of features plays a role in shape perception, and if the informativeness is reflected in the judgments of information value, then a subject would be more likely to identify an incomplete drawing of an object if the visible areas have been judged to be highly informative. If more and more parts of the object are added to the incomplete drawing, it is expected that earlier presentation of high information sections will lead to earlier recognition of the object.
2. If the informative features for object recognition are the same for adults and children, the earlier presentation of high information sections chosen by adults will lead to similar facilitation of recognition in children. On the other hand, if these features are not shared by adults and children, as many theories of shape perception have suggested, this facilitation effect would be greater for adults than for children.

Method

Subjects

The subjects were 24 first graders and 24 fifth graders from two New York City public schools and 24 college undergraduates from The City College of New York. The mean ages for the three groups were 7.0 years, 11.2 years and 21.2 years with ranges of 6.5 - 8.2 years, 10.3 - 12.3 years and 18 to 28 years respectively.

There were 18 males and 6 females among the college students and approximately equal numbers of boys and girls in the two younger age groups.

The children were enrolled in two New York City public schools. In one school, all the children were native English speakers. The other school was a Spanish-English bilingual school in which all the children had previously been classified as Spanish dominant, English dominant, other dominant or fully Spanish-English bilingual as a result of tests administered by the school. All of the subjects in the 11 year old group were either English dominant, English monolingual or fully bilingual. Nineteen subjects in the seven year old group were either English dominant, English monolingual or bilingual, while the remaining five subjects in this group were Spanish dominant. Each subject was tested using his or her dominant language.

Ten other first graders (six Spanish dominant), three fifth graders and one adult were tested and eliminated from the study because of their failure to name one of the pictures

correctly when the entire picture was finally presented to them. Data from their performances were not included in the analyses.

Stimuli and Apparatus

The stimuli were the ten pictures used in the second pilot study. They were house, chair, tricycle, cap, scissors, fish, mitten, telephone, pocketbook and lamp. Copies of the pictures are presented in the appendix to this paper. From each picture, two series of 21 slides were prepared: a systematic and a random series. The first slide in each series showed one of the 64 squares, and each subsequent slide revealed an additional square so that the twentieth slide had twenty parts of the picture. The twenty-first slide revealed the complete picture. The relative positions of the parts of the pictures were retained in the slides.

In the systematic series of slides, the first part shown was the part of the object which adults had designated in the second pilot study as having the highest perceived information content; successive pieces that were added had lower and lower average perceived information content. In the random series, the same 20 parts of the object were shown, but they were presented in random order. A different random order was used for each picture.

The slides were projected onto a rear projection screen using a Kodak carousel projector and a tachistoscopic shutter.

Procedure

One half of the subjects in each age group received the systematic presentation and the other half received the random presentation. Each subject was seated three feet from the rear projection screen so that the complete picture subtended a visual angle of 19^{0} and each small square subtended a visual angle of 2^{0}. The ten test pictures were presented in random order after a pretest using pictures of a bird and a clock cut up into four parts each and a training series showing a girl, cut up into 64 parts.

Each slide was visible to the subject for ten seconds. As each slide was shown, the subject was required to guess what the complete picture was. The experimenter proceeded to the next test picture after two consecutive correct guesses, or the presentation of all 21 slides in the series, whichever occurred first. If a child was unable to name the object in any of the pictures when he was shown the twenty-first slide in the series, i.e., the entire picture, he was automatically excluded from the study and another subject was run in his place.

The children were run in two sessions of approximately twenty minutes each while adults were run in one continuous session. The two sessions were approximately one week apart for the children.

The following instructions were given to the subjects. The experimenter began with the pictures of the pretest saying:

"I have a picture cut up into several parts and we will play a guessing game with it. Here is one part of the picture. It is a picture of something. Can you tell me what that something is?"

After the subject made a guess, the experimenter would say:

"Good. Let us add another piece to see if you are right."

This was repeated until the entire picture was visible, and the experimenter continued to the next picture, saying:

"That's very good. You can guess so quickly. You play the game very well. Let's play this game with another picture. Here is one part of a new picture. Can you tell me what the whole picture is?"

Again, after each guess, the experimenter would say:

"Good. Let us add another piece to see if you are right."

At the end of the pretest, the experimenter continued to the training picture with the following instructions:

"Very good. You are a good guesser. Now I have a picture that is cut up into many many parts, and we will play the same game with it. Here is one part of the picture. It is a picture of something. Can you tell me what that something is? I want you to guess even if you are not sure."

After each guess, the next slide was presented with the following instructions, which were repeated until the subject identified the object correctly in two consecutive guesses, or when the entire picture was shown.

"Here I have another piece of the same thing added to the picture. Tell me what the whole picture is. Remember, I want you to guess even if you are not sure."

When the entire picture was revealed, the experimenter said:

"Very good. Here is the whole picture. Sometimes you can guess what it is without seeing the whole picture. Now we will play this game with a lot of different pictures. They will not be clocks or birds or girls. Each picture will have a different thing in it."

At this point, the experimenter proceeded to the test pictures. At the beginning of each series of slides, the following instructions were given:

> "Now we will see a new picture. Here is one part of it. Tell me what the whole picture is?"

Before seeing each additional slide in the series, the subjects were told:

> "OK. Here is the same picture with another part added on. Tell me what the whole picture is?"

Whenever the subject refused to make a guess, the experimenter said:

> "I want you to guess even if you are not sure. You must guess before I can show you the next part."

When the experimenter showed the entire picture, either following two correct guesses or after the whole series was shown, he said:

> "OK. Here is the whole picture. Tell me what it is."

The above instructions were translated into Spanish by a Spanish-English bilingual graduate student at CCNY. As a reliability check, the Spanish instructions were translated back into English by a second translator who had no knowledge of the procedures and hypotheses of the experiment. The back translation was found to be almost identical to the original English version. The few differences were judged by the translators to be differences in style and vocabulary only.

Results

All subjects were able to name the two pretest items before they appeared in their entirety. However, 26 out of the 72 subjects (36%) were unable to name the mitten until either 20 parts or the entire picture was presented to them. Similarly, 46 of the subjects (64%) failed to recognize the picture of the pocketbook until at least 20 pieces were visible. Among the 14 subjects who failed to name a complete picture and were eliminated from the study, five failures involved the pocketbook, and six failures involved the mitten. Since the twentieth and twenty-first slides in each series were identical for the random and the systematic stimulus presentations and the pictures of the pocketbook and the mitten were not readily recognizable by most subjects until those levels of completeness, these two pictures were judged to be inappropriate stimuli for testing the experimental hypotheses. Thus the data from these two stimuli were excluded from the analyses.

Table 4 shows the mean number of parts needed for recognition of the stimuli by male and female subjects for each age group. An analysis of variance of these data yielded no significant sex differences, so further analyses combined the scores of male and female subjects.

Table 4

Mean number of Parts needed for Recognition by Male and Female Subjects. Experiment 1

Age	Male	Female
7.0 years	11.11	11.54
11.2 years	8.39	9.31
21.2 years	7.14	6.14

Table 5 shows the mean number of parts needed for recognition of each stimulus for the three age groups. In the trials where subjects failed to recognize the object until the complete picture was presented, the score was recorded as 21. Of the 72 subjects tested on the eight pictures that were retained, 18 subjects obtained scores of 21 for a total of 22 such scores. Since they represented only 3.8% of the entire body of scores, an analysis of variance was deemed an appropriate statistical test of the data. Thus a 3 x 2 x 8 analysis of variance was performed on the number of pieces needed for recognition. A fixed effects model was used, with between group measures for age and order of presentation and a within group measure for the eight pictures. A summary of the analysis of variance is presented in Table 6.

All main effects were found to be significantly related to the speed of recognition beyond the .01 level (Age: $F(2,66) = 53.41$; Order of presentation: $F(1,66) = 21.97$; Pictures: $F(7,462) = 73.71$). In addition, the interactions between age and pictures as well as between order of presentation and pictures were significant beyond the .01 level (Age x Pictures: $F(14,462) = 3.92$; Order of presentation x Pictures: $F(7,462) = 5.25$).

Table 5

Mean Number of Parts Needed for Recognition of Eight Pictures by Three Groups of Subjects under Random and Systematic Modes of Presentation
Experiment 1

	Age of Subjects in Years		
	7.0	11.2	21.2
Systematic Presentation:			
House	4.08	3.75	3.00
Phone	2.50	3.42	2.17
Bike	8.00	5.50	2.92
Fish	8.33	7.17	3.83
Cap	13.67	8.17	6.33
Scissors	12.17	10.05	7.67
Lamp	16.92	11.25	8.25
Chair	17.42	12.25	9.33
Random Presentation:			
House	4.75	5.33	4.33
Phone	7.67	6.42	3.33
Bike	12.58	8.67	6.67
Fish	11.58	7.33	6.75
Cap	15.00	13.58	11.33
Scissors	13.00	10.75	8.00
Lamp	15.17	11.25	4.75
Chair	18.33	15.50	11.33

Table 6

Summary of Age by Picture by Order of Presentation

Analysis of Variance. Experiment 1

Source	SS	df	MS	F
Between Subjects	4511.61	71		
Age	2470.51	2	1285.26	53.41**
Order	508.12	1	508.12	21.97**
Age x Order	6.26	2	3.13	.14
Subj. within group	1526.72	66	23.13	
Within Subjects	13277.12	504		
Pictures	6308.72	7	901.25	73.71**
Age x Pictures	670.54	14	47.90	3.92**
Pictures x Order	449.36	7	64.19	5.25**
Age x Pict. x Order	199.47	14	14.25	1.17
Pict. x Subj. w. Grp.	5649.03	462	12.23	
Total	17788.73	575		

** $p < .01$

An analysis of simple effects for the significant main effects of age and of picture differences was performed, using the Tukey HSD test (Kirk, 1968). It revealed that the performance of each age group was significantly different from that of the other two groups. Thus subjects improve their recognition performance as they grow older.

The Tukey HSD test performed on the effect of picture revealed significant differences ($p < .01$) in recognition scores for every possible pair of pictures except the following three sets:

1. house and telephone
2. bike and fish
3. all pairwise combinations of the scissors, lamp & cap.

The mean number of pieces required for recognition for each age group is graphically represented in Figure 2. The data points from each grade level have been connected for ease of comparison although the different pictures represent discrete data. It can be seen that there is a large difference in performance for the eight pictures for all age groups and that the rank orderings of the relative level of difficulty of the pictures are quite consistent across the three age groups. The significant interaction between age and pictures found in the analysis of variance seems to stem from the fact that children and adults differed in their performance on the difficult pictures, but not on the easy pictures, as shown in the test of simple main

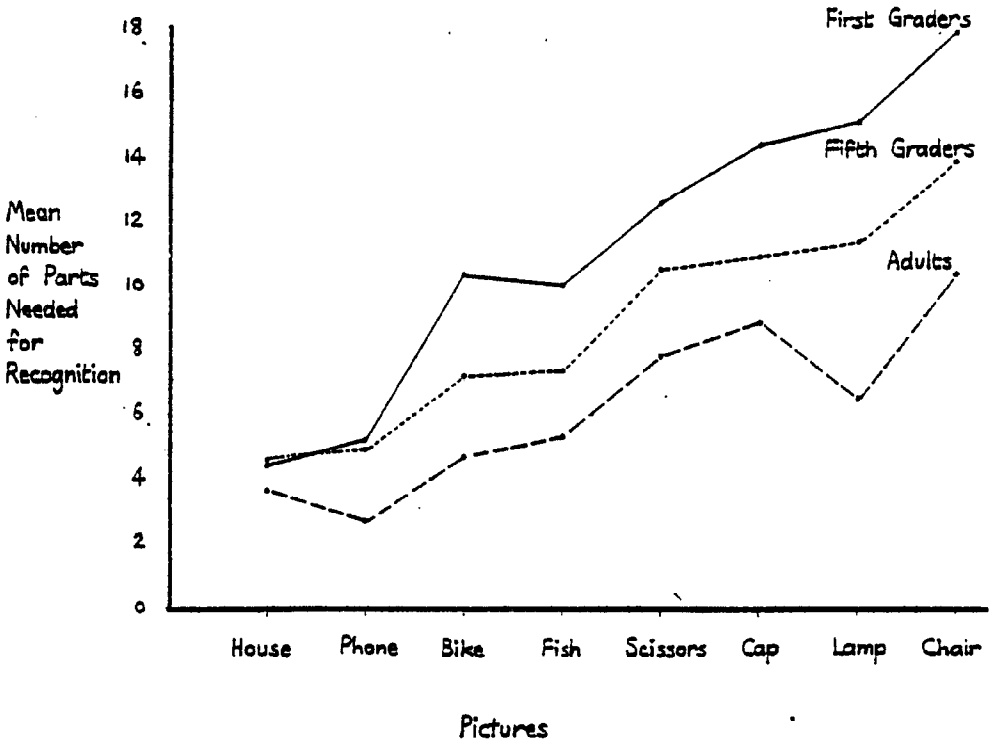


Figure 2. Recognition Performance of Three Groups of Subjects. Experiment 1.

effects for this interaction (see Table 7). Specifically, there was no significant difference in recognition performance for the three age groups for the two easiest pictures, house and telephone. Among the pictures of intermediate difficulty (bicycle, fish, scissors and cap), there were significant differences in the performance of the three age groups for the bike and the cap at the .05 level of significance (Bike: $F(2,528) = 3.37$; Cap: $F(2,528) = 3.41$). For the most difficult pictures, chair and lamp, the age differences in performance was significant beyond the .01 level (Lamp: $F(2,528) = 10.05$; Chair: $F(2,528) = 6.28$).

The significant interaction between pictures and order of presentation of the parts of the pictures is graphed in Figure 3. It shows the significant main effect of order of presentation, that subjects receiving the systematic presentation generally needed fewer parts of the picture for correct identification than subjects receiving the random order presentation. Figure 3 seems to suggest that the significant interaction between pictures and order is due to the fact that there was a greater difference between random and systematic presentations for the easier pictures than for the harder pictures. The mean number of pieces necessary for recognition in the random and systematic conditions for the easier pictures (house, phone, bicycle, fish) and the harder pictures (scissors, cap, lamp, chair) are shown in Table 8. An analysis of variance of these data confirmed

Table 7

Summary Table of Tukey HSD Test of Simple Main Effects of the Age by Pictures Interaction

Experiment 1

Presence of Age Differences for each Picture:

Source	SS	df	MS	F
House	10.75	2	5.385	0.10
Phone	81.33	2	40.66	0.75
Bike	366.36	2	183.18	3.37*
Fish	263.58	2	131.79	2.42
Scissors	272.11	2	136.06	2.50
Cap	371.03	2	185.52	3.41*
Lamp	1092.53	2	546.26	10.05**
Chair	683.36	2	341.68	6.28**
Error		528	54.37	

Presence of Picture Differences at each Age Level

Source	SS	df	MS	F
7 year olds	3969.65	7	567.09	46.37**
11 year olds	1860.37	7	265.77	21.73**
Adults	1149.25	7	164.18	13.42**
Error		462	12.23	

* $p < .05$ ** $p < .01$

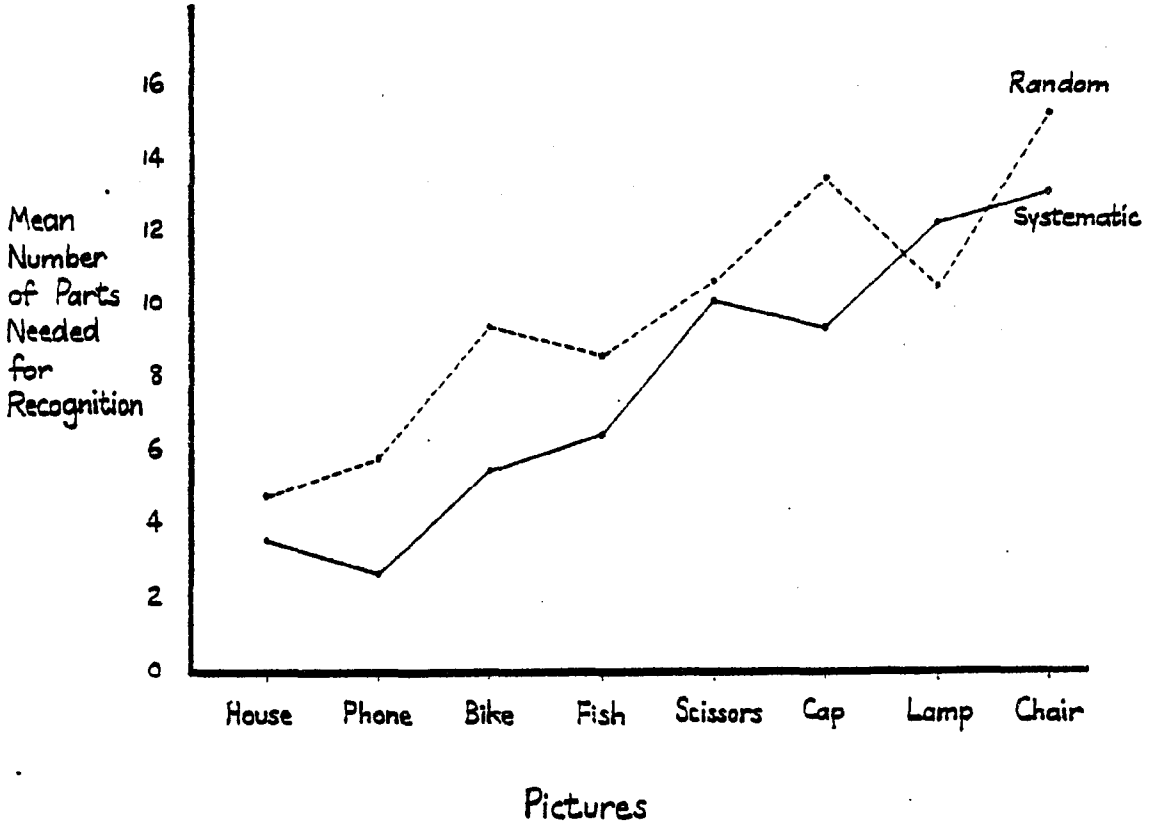


Figure 3 Recognition Performance for Random and Systematic Orders of Presentation Experiment 1

Table 8

Mean Number of Parts Needed for Recognition of
Easy and Difficult Pictures in Two Modes of Stimulus Presentation
Experiment 1

Type of Picture	Systematic Order	Random Order
easy	4.56	7.12
difficult	11.14	12.33

that superior recognition performance is obtained for the systematic presentation of picture parts ($F(1,70) = 8.88$, $p < .01$) and for the easier pictures ($F(1,70) = 247.91$, $p < .01$). The interaction between order of presentation and difficulty of picture was significant beyond the .07 level ($F(1,70) = 3.33$).

Discussion

The data from this study support the experimental hypothesis that when high information sections of a picture are presented first, both adults and children require fewer pieces of the picture in order to identify it. They confirm the thesis that some parts of pictures carry more information than others for recognition and that these informative parts are not arbitrary, but predictable and consistent for subjects of different ages. Since the operational definition of informativeness used in this study has been shown to correlate with exploratory eye movements, these data also lend support to theories of form perception that predict accurate form recognition to be mediated by the apprehension of relevant features through exploratory eye movements and fixations.

The data also replicate previous findings (Schober & Schober 1919; van der Torren, 1907; Goldstein & Mackenberg, 1966) that the ability to recognize incomplete pictures increases with age. However, the absence of an age x order of presentation

interaction contradicts the belief that the cues that are generally more informative for adults are different from those informative for children. The poorer recognition performance of the children cannot then be attributed to the informativeness of the cues provided for recognition. Rather, the children must differ from adults primarily in the way they utilize these informative cues for recognition. Several alternatives are possible.

First, it is possible that the absolute amount of information that the subject is able to extrapolate from each stimulus cue, regardless of its degree of informativeness, increases with age. In this way, although young children do receive as much additional information from the systematic stimulus presentation as adults do, the overall amount of information they gain is less than for adults, accounting for the age differences in recognition performance.

Alternatively, the absolute amount of information gleaned from each stimulus cue may be the same for adults and children, but the children may be less able to integrate the information from the separate parts into a whole, especially when the features are not spatially adjacent to each other.

The importance of an integrative ability in recognition has been emphasized by Hochberg (1968) who claims that an efficient schematic map must contain information about the relationships between features in addition to information about the identity

of the features. Since children presumably have schematic maps that contain both fewer features and less information concerning the relationships between them, they may be less able to recognize incomplete drawings due to their inability to coordinate the disparate parts even though the essential features may be present in their schematic maps.

Data concerning children's integrative abilities during visual recognition have been collected by Girgus & Hochberg (1970) who presented subjects of difference ages with outline shapes either in their entirety on an index card or in a sequential piecemeal fashion in a movie. Subjects of all ages demonstrated perfect recognition in the former mode of presentation, but during sequential presentation, correct recognition improved as a function of age, suggesting that young children may have difficulty integrating information presented separately in time. Further, empirical support of this view can be seen in Schober & Schober's (1919) finding that the child's awareness of a feature is comparable to that of an adult's at age four, but the ability to utilize the cue in the larger configuration is still not fully developed.

Hochberg's (1968) interpretation is also consistent with the views of other theorists. Piaget (1969), Brunswik (1954) and Gibson (1969) all allude to the development or learning of multiple cues. Piaget (1969) believes that, at six or seven

years, some children may not have the ability to decenter their attention from a small number of cues in order to coordinate the large number of cues actually in the stimulus. In Brunswik's (1954) formulation, the ability to recognize the significance of cues which always occur together is the result of repeated exposure to their joint occurrence. Since young children have had less experience, and presumably deal less effectively with joint probabilities, they can only extract information from individual cues while adults can fully utilize the additional information provided by multiple co-occurring cues to achieve speedier recognition.

Although Gibson (1969) maintains that the differentiation and search for invariants are essential to recognition of objects, she sees them as processes utilized by adults and children alike. What distinguishes adult perceptual processes from those of the child's in Gibson's view is the adult's ability to discover higher order structures or embedded clusters of differentiated features in an object. In this experiment, while the seven year olds may have differentiated all the features provided, they may lack the ability to coordinate the features into meaningful clusters, so their performance lagged behind adults in both the random and systematic presentations.

A third possible perspective on the child's poor recognition performance is that the youngest children can only obtain information from some of the cues provided, in an all or none fashion.

Even among the informative cues, there may be a number of parts that the child is not able to utilize. This is consistent with Gibson's (1969) claim that the child only benefits from the cues that he has successfully differentiated. Although he is more likely to have differentiated the cues chosen by the adults as the informative cues, he is still only able to use a portion of them, thus recognition can be expected to be poorer for the children in both the random and the systematic orders of presentation.

The hypothesis that age changes in recognition are a function of the number of informative cues that the children have differentiated or hold in their schematic maps finds further support from an interpretation of the significant age x picture interaction. While there was no difference between the recognition scores of adults and children for the easier pictures, children performed more poorly than adults on the difficult stimuli. It is possible that the simple pictures either require fewer cues for recognition, or have several cues of especially high information value that provide adequate information for recognition. This would mean that children only have to pick up a few cues in order to recognize the picture. For the difficult pictures, each cue may be less informative individually and more parts may be needed for recognition. However, the children are not able to utilize the cues of lower informativeness identified

by adults because these cues have not been differentiated or integrated into their internal representations. Thus, the children perform poorly in comparison with the adults. Such an interpretation is also consistent with Piaget's (1969) belief that children centrate a small number of features of the picture and ignore others. For the easier pictures with only a few prominent cues, it is very likely that children normally focus their attention on the same extremely prominent cues that permit easy recognition. However, this selective strategy would only aid their performance on the easier pictures with a small number of very informative cues and not on the more difficult pictures that require a wide range of cues for recognition. If the easy pictures can be construed as having several cues of extremely high information value, a systematic order of presentation would obviously produce greater facilitation in recognition for easy pictures than for difficult pictures where the differences in the informativeness of successively-presented cues is more similar to the differences found in a random presentation. Support for this interpretation was obtained in the form of the appropriate interaction between picture difficulty and order of presentation.

Statistically reliable differences were found between ease of recognition of the eight pictures studied. From the present data, it is not possible to infer the cause of the differences because the selection of the particular pictures of common

objects used in this study was relatively unsystematic. These differences may have been caused by any of a variety of factors previously found to affect recognition, such as the familiarity (Nelson, 1972), the value (Bruner & Goodman, 1947), and the complexity (Vanderplas & Garvin, 1959) of the objects, the manner in which the objects are depicted, i.e. the perspective (Vurpillot & Brault, 1959) or orientation (Ghent & Bernstein, 1961) of the objects, the variability in the presence of and number of informative features, and the level of informativeness of the features used. There is evidence in the present experiment to suggest that the easy pictures may have contained a greater number of highly informative features than the more difficult pictures.

CHAPTER FOUR

EXPERIMENT TWO

The results of Experiment 1 confirm previous findings (Schober & Schober, 1919; van der Torren, 1907; Goldstein & Mackenberg, 1966) that recognition for incomplete pictures improves with age. They also indicate that information relevant for picture recognition by adults is similarly relevant for children. However, the data suggest that children and adults utilize the information that is provided for recognition in different ways. These differences may be due to any or all of the following alternatives:

1. The amount of information extraction per cue may increase with age.
2. The ability to integrate information from different parts of a picture may increase with age.
3. From among the informative cues, young children may be only able to extract information from the cues that they have differentiated.

The second experiment tries to test the third alternative more directly.

In the incomplete pictures given for identification in Experiment 1, the cues chosen by adults as highly informative may also contain many cues that are informative for the children.

Thus, systematic presentation of cues beginning with those of highest information value for adults and moving gradually to those of lower informativeness facilitated children's performance as much as it facilitated the adults' performance relative to performance based on random presentation of the same cues. However, the children are still at a disadvantage compared to adults because they may be able to utilize only a fraction of the cues presented, regardless of their informativeness for adult recognition. If this hypothesis is correct, then presenting children with the features that are informative for them should improve their recognition performance relative to their recognition performance based on the cues that adults have chosen.

The second pilot study provided data about children's judgments of the informativeness of various parts of pictures of common objects. Those features judged to have high informativeness by children may indeed be the same as those that children utilize for recognition. We have already noted that the spatial distribution of children's choices in regard to information content is similar to the spatial distribution of children's visual fixations (Mackworth & Bruner, 1970). It has been suggested that frequent fixations of a feature will lead to the differentiation of that feature into the appropriate internal representation (Gibson, 1969; Neisser, 1967; Hochberg, 1968; Piaget, 1969), and thereby increase the informativeness of the feature for recognition.

If it is true that:

1. The pieces of the pictures rated as high in information content by children are the same features that receive more attention in free-viewing, and
2. Features receiving more attention become informative for recognition through their differentiation or incorporation into the children's internal representation of objects, and
3. Children's scan patterns are maximally efficient for them,

it follows that presenting pictorial information to children in the order determined to be most informative by their peers should improve their recognition performance.

Piaget (1969) would disagree with the last of these assumptions. He attributes poorer recognition performance in children to their inability to examine the stimulus thoroughly and systematically. In Piaget's view, children tend to center their attention on a particular part of the picture salient for them and pay little heed to other areas. Moreover, during reconstruction, young children tend to be unsystematic in their cue utilization, often centering their attention on some aspects of the object and paying no heed to other aspects pertinent to their schemas. In this way, features informative at the time of schema formation may be neglected during recognition. Thus, as the process of reconstruction becomes more organized with age, recognition would improve.

Research on scanning patterns of children performing various perceptual tasks has often substantiated Piaget's prediction (Kessen, 1967; Salapatek, 1968; Mackworth & Bruner, 1970; Vurpillot, 1968; Olson, 1970) and characterized the child's eye movements as inefficient and unsystematic. Whereas theorists such as Gibson (1969) and Hebb (1949) believe that such differential attention leads to more accurate recognition, Piaget implies that it detracts from accurate percepts, so that imposing a more systematic or adult form of visual input would probably improve recognition performance in children.

Experiment 1 has shown that when more and more features are added to an incomplete picture for recognition, earlier presentation of high information sections chosen by adults leads to earlier recognition by children. Experiment 2 will test whether the earlier presentation of high information sections chosen by the children's peers will lead to even earlier recognition by children relative to their performance in Experiment 1. If Piaget (1969) is correct that children's scan patterns detract from accurate perceptions, then providing a child with the presumably more efficient input patterns of adults should improve his recognition performance relative to providing him with the less efficient input patterns of his peers. If, on the other hand, the scan patterns used by children are maximally efficient for them, and lead to the differentiation of informative cues for recognition,

as in Gibson's (1969) view, then presenting pictorial information to them in a manner closely related to their own classification of information value would produce better recognition performance than presenting pictorial information in the order dictated by adult judgments.

Method

Subjects

Twenty-four third graders from a bilingual public school in New York City and twenty- four undergraduate students at the City College of New York served as subjects. There were an equal number of males and females in each group. The mean ages of the two groups were 9.0 years (range 8.5 - 9.7 years) and 21.6 years (range 15 - 40 years) respectively. The children were all English dominant or completely Spanish-English bilingual children according to bilingual testing administered by the school.

Two other adults and two children were partially tested and eliminated from the study because they were unable to name the object in one of the pictures when it was shown in its entirety.

Stimuli and Apparatus

Two series of slides were prepared in the same way as Experiment 1. The first set of slides was identical to the

systematic series in Experiment 1, where the first slide showed the piece of the picture given the highest median information rank according to the adult rankings, with pieces of lower and lower information rank added in subsequent slides.

The second set of slides was prepared according to the median information ranks obtained from eight year old subjects in the second pilot study. Again, each series began with the piece of the picture given the highest median rank, with pieces of lower and lower information value added in subsequent slides.

The group of subjects who gave information rankings for the child series were similar in age and background to the children employed in the present study. There were 8 boys and seven girls in the pilot group and their ages ranged from 8.3 to 9.3 years with a mean of 8.6 years. They were bilingual or English dominant children enrolled in the same public school as the experimental subjects. The subjects who gave information rankings for the adult series were eight males and seven females from a similar background. Their mean age was 22 years.

The ten pictures were divided into high agreement pictures and low agreement pictures, based on the amount of difference between adult and child rankings in the pilot data. The high agreement pictures were the house, bicycle, scissors, telephone and pocketbook. For each high agreement picture, the adults and children agreed on six or more pieces in their choices of the ten most informative pieces. They also concurred in 13

or more pieces among the 20 pieces that were chosen. The low agreement pictures were the chair, fish, cap, mitten and lamp. For these pictures, the adults and children agreed on fewer than five of the ten most informative pieces and agreed on less than 12 of the 20 pieces chosen. In other words, for the high agreement pictures, the adults and children had 13 or more pieces that were identical, with less than 12 identical pieces for the low agreement pictures.

Procedure

Half the subjects in each age group received the pictures with the pieces added according to adult rankings, and the other half of the subjects received slides with the pieces added in accordance with the rankings given by eight year olds. The subjects were run in the same manner as in Experiment 1, using the same equipment and instructions.

Results

All the subjects were successful in naming the pretest items, but two children and two adults were eliminated from the study because of their failure to name the pictures of the mitten or the pocketbook when the whole picture was finally presented to them. Nineteen of the 48 subjects (40%) were unable to name the mitten until 20 parts or more of the picture were

visible and 23 subjects (48%) failed similarly on the picture of the pocketbook. Since these two stimuli often required 20 or more 20 pieces before they could be recognized by most subjects, they were inappropriate stimuli for testing the experimental hypothesis and so the data for these two pictures were excluded from the analyses.

Table 9 shows the mean number of parts needed for recognition by male and female subjects in each age group. An analysis of variance on these data showed no significant sex differences so the data for males and females were combined in all further statistical analyses.

Two mean recognition scores were calculated for each subject, one for the four high agreement pictures and one for the four low agreement pictures. A summary of these means are presented in Table 10. A 2 x 2 x 2 fixed effects analysis of variance was performed on these data with age and type of information input as between group measures and high and low agreement pictures as a within group measure. The summary table for this analysis is shown in Table 11. As in Experiment 1, age was found to be significantly related to the number of parts required for recognition ($F(1,44) = 81.36$, $p < .01$). The low agreement pictures were found to be more difficult to identify than the high agreement pictures ($F(1,44) = 225.38$, $p < .01$).

Table 9

Mean Number of Parts Needed for Recognition by Male and Female Subject. Experiment 2.

Age	Male	Female
9.0 years	10.09	10.76
21.6 years	6.12	6.06

Table 10

Mean Number of Parts Needed for Recognition of High and Low Agreement Pictures by Children and Adults in Two Orders of Stimulus Presentation. Experiment 2.

	Cues determined by nine year olds		Cues determined by adults	
Age	High Agreement Pictures	Low Agreement Pictures	High Agreement Pictures	Low Agreement Pictures
9.0	7.42	14.69	6.69	13.04
21.6	4.71	8.10	4.25	7.33

Table 11

Summary Table of 2 x 2 x 2 Analysis of Variance

Experiment 2

Source	SS	df	MS	F
Between Subjects	7242.02	47		
Age	4561.00	1	4561.00	81.36**
Order	194.85	1	194.85	3.48*
Age x Order	19.69	1	19.69	0.35
Subj. within groups	2466.48	44	56.06	
Within Subjects	8040.31	48		
Agreement	6062.66	1	6062.66	255.38**
Agreement x Age	765.94	1	765.94	28.47**
Agreement x Order	22.66	1	22.66	0.84
Age x Order x Agreement	5.48	1	5.48	0.20
Agree. x subj. w. grp.	1183.46	44	26.90	
Total	15282.33	95		

* $p < .1$

** $p < .01$

Although the children's rankings consistently required more pieces for recognition on the average than the adult rankings required, the effect was only marginally significant ($F(1,44) = 3.48$, $p < .1$). A significant interaction between the variables of age and type of picture ($F(1,44) = 28.47$, $p < .01$) revealed that the difference between the adult and children recognition scores was much larger for the low agreement pictures than for the high agreement pictures. None of the other interactions was statistically significant.

The pictures found to be more difficult to identify in Experiment 1 were also more difficult in Experiment 2. The Pearson Product Moment Correlation Coefficient for the mean number of pieces required for recognition for each picture in the two studies, as shown in Table 12, was +.95. Among the high agreement pictures, three pictures -- house, phone and bicycle -- were the easiest to identify in both studies. The fourth picture among the high agreement pictures ranked fifth in difficulty in Experiment 1 and sixth in Experiment 2.

Discussion

The results of Experiment 2 replicate the previous finding that recognition performance on incomplete pictures improves with age of the subject. Both experiments also showed consistent

Table 12

Mean Number of Parts Needed for Recognition of Eight Pictures in Experiments 1 and 2.

Picture	Experiment 1	Experiment 2
House	4.21	2.96
Phone	4.25	3.00
Bike	7.39	4.83
Fish	7.50	5.54
Scissors	10.31	12.27
Cap	11.35	12.15
Lamp	11.26	12.73
Chair	14.03	12.85

differences between pictures in ease of recognition for subjects of all ages; pictures that are easier for adults to recognize are also easier for children.

However, the crucial experimental question -- whether a child's recognition performance would be better when he was presented with pictorial information according to information rankings provided by his peers or when he was presented with pictorial information according to information rankings provided by adults -- remains unanswered.

Theorists such as Gibson have suggested that peer judgments of information content will be maximally efficient since they presumably reflect a shared set of differentiated features that can be utilized during recognition. Strong support for this point of view would have been provided by significantly superior performance for subjects who were given the pieces of the pictures chosen by their peers. This would be especially true for the low agreement pictures if the type and order of choices in the high agreement pictures were sufficiently similar for adults and children to prevent any difference in recognition performance. Investigators adopting this theoretical position would predict one of two possible significant interactions. The first would be a significant age x order interaction in favor of peer group choices of recognition cues, i.e.,adults perform better when given adult cues and children perform better when given children's

cues. The second possibility would be a significant three way interaction between age, order of information presentation and type of picture, in which the second order interaction just described would be found for low agreement pictures only. Since no such interactions were found to be significant, Gibson's hypothesis was not supported by the experimental data.

A strong support for Piaget's position would show for all subjects, regardless of age, a significantly superior performance for those subjects given the pieces of the picture according to the adult rankings as compared with those who received the children's rankings. Such a difference was consistently obtained, but it was only marginally significant ($p<.1$).

The absence of any significant effects of order of presentation suggests that subjects recognize common objects equally well when presented with either adult or child rankings of information content. This may imply that even nine year olds in the study are flexible in their cue utilization. It is possible that no particular group of features is essential for recognition, as long as the combination of features is sufficient to evoke the subject's mental representation of the object or to tap into the cues that he is able to distinguish from other cues.

The difference in recognition performance between children and adults was more than twice as great for the low agreement pictures as for the high agreement pictures. It was argued

from the data in Experiment 1 that the easily recognizable pictures may carry several cues of especially high informativeness. The same argument could explain the significant interaction between age and agreement in rankings, given that high agreement pictures are also the easy pictures to recognize. If the easy pictures possess several highly informative cues that children acquire early or differentiate early, both adults and children might tend to rank these parts of the picture as having high information content, giving the high agreement in ranking. During recognition, these prominent cues alone may be adequate for the child or adult to identify the object, leading to smaller differences in their recognition performance.

Among the difficult pictures, it is possible that the difference in informativeness between parts of highest and lowest informativeness is extremely small, so it is unlikely that children as a group will pay any special attention to any part of the picture in particular. However, finer discriminations will be made by adults who attend to details that children might ignore.

CHAPTER FIVE

GENERAL DISCUSSION

The development of cue utilization

The data from Experiments 1 and 2 demonstrate that pictorial cues determined to be informative for recognition by adult subjects are superior in inducing faster recognition than either randomly selected cues or cues chosen by children. The magnitude of the difference between the effectiveness of adult-ordered and randomly ordered cues is presumably greater than the difference between the effectiveness of cues chosen by children and adults, judging by the levels of statistical significance ($p < .01$ vs $p < .1$) of the order effects in Experiments 1 and 2. This suggests that presenting subjects with the pictorial cues in the sequence chosen by nine year olds, as we did in Experiment 2, would probably lead to faster recognition than presenting adult-chosen cues in random order, as we did in Experiment 1. This suggests that, although information rankings by nine year olds in pilot study 2 may have shown less concordance than adult rankings, they are far from random and apparently contain relevant, informative cues for recognition.

It is also important to note that although the ease of recognition is affected by the order in which the cues are presented, the majority of the subjects in the two studies were able to

identify the objects in the pictures, before the entire picture was visible, regardless of the cue input. This implies that considerable flexibility in cue utilization during recognition of common objects is achieved as early as seven years of age. These two studies demonstrate that recognition in these children is probably based on the use of a number of mutually substitutable cues. Perhaps further research with children younger than seven years may provide insight into the development of multiple cue usage and possibly offer support for Piaget's view (1965) that four to seven years olds who are in a preoperational stage of development may be unable to deal with a large variety of cues and are thus quite inflexible in their cue utilization.

The effects of cue informativeness on picture recognizability

Consistent and statistically reliable differences in the difficulty levels of the eight pictures were found in the two studies. While it is premature to postulate any causes for these differences in ease of recognition of specific objects, it is possible that the recognizability of the easy pictures in this study and perhaps of objects recognized early in a child's perceptual development may be attributed to the presence of a number of cues of high informativeness in these drawings. This explanation is supported by the three interactions obtained between the drawings and other experimental variables.

If the preceding hypothesis concerning the relationship between cue informativeness and recognizability is correct, one might also expect that recognizability would be further reduced for all pictures, and especially for the easy pictures, when the parts of the pictures are added in reverse order from the systematic order suggested by adults information rankings.

Some theoretical conclusions

Although this dissertation was designed to develop a methodology to examine cue utilization by children and adults, rather than to test the accuracy of different theories of recognition, some of the findings are relevant to theoretical speculations.

While the physiological bases of Hebb's (1949) theory could not be tested in these experiments, his predictions that features more often fixated are more likely to be informative for recognition received indirect support in Experiment 1 from the fact that areas of high judged information content, which presumably are fixated more often, do lead to easier recognition. Further, the fact that different orders of presentation of the same cues produced differences in recognition performance is consistent with his notion that the order in which the stimulus elements are explored create phase sequences for each object that are utilized during recognition.

The present experiments also fail to test Brunswik's theory of ecological validity directly, although they do suggest

possible ways of attacking the problem. Bruner (1957) has suggested that it is not appropriate to consider the stimulus in isolation because the utilization of cues beyond the physical confines of the stimulus itself, such as the value and the familiarity of the stimulus, have profound effects on how we deal with the stimulus. If information outside of the stimulus is utilized in the recognition process, age changes in recognition performance must be the result of processes more complex than exploratory eye movements and must involve such factors as cultural learning and the use of various coding systems. One can test the relative contributions of cues within the object and those surrounding the object, using an extension of the present experimental paradigm. For example, the picture of the chair can be presented to the subject for recognition imbedded in a living room, a playground, a forest and a parking lot. It is very likely that the features surrounding the object will be more powerful cues for the children than are the features contained in the picture of the object. This effect may be less dramatic for adults, as the study by Schober & Schober (1919) has suggested that children are more affected by the total situation than adults.

Hochberg's (1968) prediction that it is possible for a subject to misidentify an object even when all the stimulus cues are available was dramatically supported in that some subjects in each age group failed to identify at least one of the complete

pictures finally presented to them. This is an amazing result when one recalls that these particular pictures were used in these studies because they were easily named by kindergarten children. It is possible that during the recognition process dictated by these studies, the subjects were adhering to an erroneous schematic map. When the entire picture was shown, the subject may still have been preoccupied with the incorrect schematic map and thus was unable to take the fresh supply of information into account. The experimenters' observations of subjects who failed to name a picture indicated that the incorrect identifications were the same as or similar to some response that the subjects had recently given. These anecdotal pieces of evidence lend support to the theorists that view perception as an active process of matching external input to stored information or expectancies. Such theorists include Hochberg (1968), Piaget (1968), Neisser (1967) and Bruner (1957). Since subjects as young as seven years experience the same problem of misidentification as adults, it also suggests that these children may be employing the same matching strategies as adults, although the content and the accuracy of their attempts may be different from those of the adults. Piaget's hypothesis concerning the role of centration in form recognition was tested without producing any definitive results. Gibson's (1969) suggestion that a child's recognition performance is a function of the number of cues he has differentiated was not substantiated.

The main contribution of these studies is the demonstration that the presentation of ranked judgments of information content from adults is a promising avenue for investigations concerning information utilization in form recognition. The data from Experiment 1 have shown that such presentations may provide a viable alternative to eye movement recordings which are often inaccurate and cumbersome, especially with young subjects.

Many assumptions of the present studies remain to be substantiated. First the problem of finding a general metric to discover the essential features for recognition of objects has remained unsolved. Only a rank ordering of the information content of arbitrary divisions has been obtained. Nothing is known about the reasons behind the choices of the parts, or the nature of the informative parts themselves. In order to find the elements that differentiate the high information parts of pictures from the low information parts, one must examine the nature of the different parts. The discovery of such generalities has been attempted by Brown & Owen (1967) who performed factor analyses on subjects' judgments of similarity and complexity of random forms. Similar research could be performed on judgments of information content in everyday objects. Brown & Owen (1967) have restricted their generalizations to the physical properties of the forms. Perhaps research on common objects could also measure properties of the parts of objects such as the subjects' knowledge of the functions of the parts, or the emotional impact

of the part of the object.

Although it has been demonstrated that judged information rankings obtained from adults can provide us with an understanding of information processing during picture recognition, the accuracy and reliability of the children's information rankings and their relationship to children's fixation patterns remains unclear.

Theoretically, research on eye movement patterns in children should reveal a great deal about the development of visual information processing and perception in children. However, advances in this area have been hampered by the inaccuracy and cumbersome nature of eye movement recordings with children. If future research is able to establish strong correlations between children's information rankings and their visual fixation patterns, judgments of information content may be seen as an alternative to eye movement recordings and spur new progress in this area.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Two experiments have been described which explored the development of information processing in children. In each experiment, subjects were asked to identify ten pictures of common objects presented at increasing levels of completeness. The number of parts needed for recognition decreased with age and with the earlier presentation of more informative parts, as determined by judged information content. Information ratings by adult subjects were more effective in producing earlier recognition than either ratings by nine year olds or the random addition of information.

From these data, the following conclusions can be made concerning recognition of drawings of common objects:

1. Judgments of informativeness of arbitrary divisions of drawings by adults can provide a reasonably reliable measure of informativeness of the parts of pictures for recognition.
2. Informative cues for adults are also informative for children as young as seven years.
3. Judgments of informativeness by nine year olds, though less reliable as a measure of informativeness, nevertheless show that nine year olds are able to understand and categorize information.

4. By seven years, most children are able to utilize multiple cues for object recognition.
5. Age improvements in recognition performance can be attributed to differences in the utilization of informative cues.

REFERENCES

Aiken, L. S. & Williams, T. M. Development of multiple dimension use in form classification. Child Develpm., 1975, 46, 123-132.

Attneave, F. Some informational aspects of visual perception. Psychol.Rev., 1954, 61, 183-193.

Baker, M. A. & Loeb, M. Implications of measurements of eye fixations for a psychophysics of form perception. Percept. & Psychophys., 1973, 13, 185-192.

Brown, D. R. & Owen, D. H. The metrics of visual form: methodological dyspepsia. Psychol. Bull., 1967, 68, 243-259.

Bruner, J. S. On perceptual readinesss. Psychol. Rev., 1957, 64, 123-152.

Bruner, J. S. & Goodman, C. C. Value and need as organizing factors in perception. J. abnorm. soc. Psychol., 1947, 47, 33-44.

Brunswik, E. Reasoning as a universal behavior model and a functional differentiation between "perception" and "thinking". Paper read at the International Congress in Montreal, 1954. Reprinted in Hammond, K. R. (Ed.) The psychology of Egon Brunswik. New York: Holt, Rinehart & Winston, Inc., 1966. pp 487-494.

Fantz, R. L. Pattern vision in newborn infants. Science, 1963, 140, 296-297.

Ghent, L., & Bernstein, L. Influence of the orientation of geometric forms in their recognition by children. Percept. mot. Skills. 1961, 12, 95-101.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts, 1969.

Gibson, E. J. , Gibson, J. J., Pick, A. D. & Osser, H. A developmental study of the discrimination of letter-like forms. J. comp. physiol. Psychol., 1962, 55, 897-906.

Girgus, J. S. A developmental approach to the study of shape processing. J. exp. child. Psychol,, 1973, 16, 363-374.

Girgus, J. S. & Hochberg, J. E. Age differences in sequential form recognition. Psychon. Sci., 1970, 21, 211-212.

Goldstein, A. L. & Mackenberg, E. J. Recognition of human faces from isolated facial features : a developmental study. Psychon. Sci., 1966, 6, 149-150.

Gollin, E. S. Factors affecting visual recognition of incomplete objects: a comparative investigation of children and adults. Percept. mot.Skills, 1962, 15, 583-590.

Gollin, E. S. Perceptual learning of incomplete pictures. Percept. mot.Skills, 1965, 21, 439-445.

Goodnow, J. J. Rules and repertoires, rituals and tricks of the trade: social and informational aspects to cognitive and representational development. In Farnham-Diggory, S. (Ed.) Information Processing in children. New York: Academic Press, 1972, pp. 83 -102.

Hebb, D. O. The organization of behavior. New York: John Wiley & Sons, Inc., 1949.

Hochberg, J. E. In the mind's eye. In Haber, R. N., (Ed.) Contemporary theory and research in visual perception. New York: Holt, Rinehart & Winston, Inc., 1968.

Hochberg, J. E. The representation of things and people. In Gombrich, E. H. , Hochberg, J. E. & Black, M. (Eds.) Art, Perception and Reality. Baltimore: The Johns Hopkins University Press, 1972.

Hochberg, J. E. & Brooks, V. Pictorial recognition as an unlearned ability: a study of one child's performance. Am. J. Psychol., 1962, 75, 624-628.

Kessen, W. Sucking and looking: two organized congenital patterns of behavior in the human newborn. In Stevenson, H. W., Hess, E. H. & Rheingold, H. L. (Eds.) Early behavior: comparative and developmental approaches, New York: John Wiley & Sons, 1967, pp 147-179.

Kirk,R. E. Experimental Design: Procedures for the behavioral sciences. Belmont, California: Brooks/Cole Publishing Co. 1968.

Loftus, G. R. Eye fixations and recognition memory for pictures. Cognitive Psychol., 1972, 3, 525-551.

Mackworth N. H. & Bruner, J. S. How adults and children search and recognize pictures. Human Develpm., 1970, 13, 149-177.

Mackworth, N. H. & Morandi, A. J. The gaze selects informative details within pictures. Percept. & Psychophys., 1967, 2, 547-551.

Neisser, U. Cognitive Psychology. New York: Appleton-Century-Crofts, 1967.

Nelson, K. The relation of form recognition to concept development. Child Develpm., 1972, 43, 67-74.

Nodine, C. F. and Simmons, F. G. Processing distinctive features in the differentiation of letterlike symbols. J. exp. Psych., 1974, 103, 21-28.

Nodine, C. F. & Steuerle, N. L. Development of percpetual and cognitive strategies for differentiating graphemes. J. exp. Psychol., 1973, 97, 158-166.

Noton, D. & Stark, L., Scanpaths in eye movements during pattern perception. Science, 1971, 171, 308-311.

Olson, D. R. Cognitive development: the child's acquisition of diagonality. New York: Academic Press, 1970.

Piaget, J. The construction of reality in the child. New York: Basic Books, 1954.

Piaget, J. The child's conception of number. New York: Norton, 1965.

Piaget, J. On the development of memory and identity. Barre, Mass.: Clark University Press and Barre Publishers, 1968.

Piaget, J. The mechanisms of perception. New York: Basic Books, 1969.

Pollack I. & Spence, D. Subjective pictorial information and visual search. Percept. & Psychophys., 1968, 3, 41-44.

Potter, M.C. On perceptual recognition. In Bruner, J. S., Olver,

R. R. & Greenfield, P. M. (Eds.) Studies in cognitive growth. New York: John Wiley & Sons, Inc., 1966, pp 103-134.

Salapatek, P. Visual scanning of geometric figures by the human newborn. J. comp. physiol. Psychol, 1968, 66, 247-258.

Salapatek, P. A. & Kessen, W. Visual scanning of triangles by the human newborn. J. exp. Child Psychol., 1966, 8, 155-167.

Schober, G. & Schober, A. Ueber Bilderkennungs und Unterscheidungsfähigkeit bei kleinen Kindern. Bh. z. ang. Psychol., 1919, 94-137.

Vanderplas, J. M. & Garvin, E. A. Complexity, association value, and practice as factors in shape recognition following paired associates training. J. exp. Psychol., 1959, 57, 155-163.

Van der Torren , I. Ueber das Auffassungs und Unterscheidungsvermogen fur optische Bilder bei Kindern. Zeit. angew. Psychol., 1907, 1, 189-232.

Vurpillot, E. The development of scanning strategies and their relation to visual differentiation. J. exp. Child Psychol., 1968, 6, 632-650.

Vurpillot, E. & Brault, H. Étude expérimentale sur la formation des schemes empiriques. L'Annee Psychol., 1959, 59, 381-394.

Wohlwill, J. F. Developmental studies of perception. Psychol.Bull. 1960., 57, 249-288.

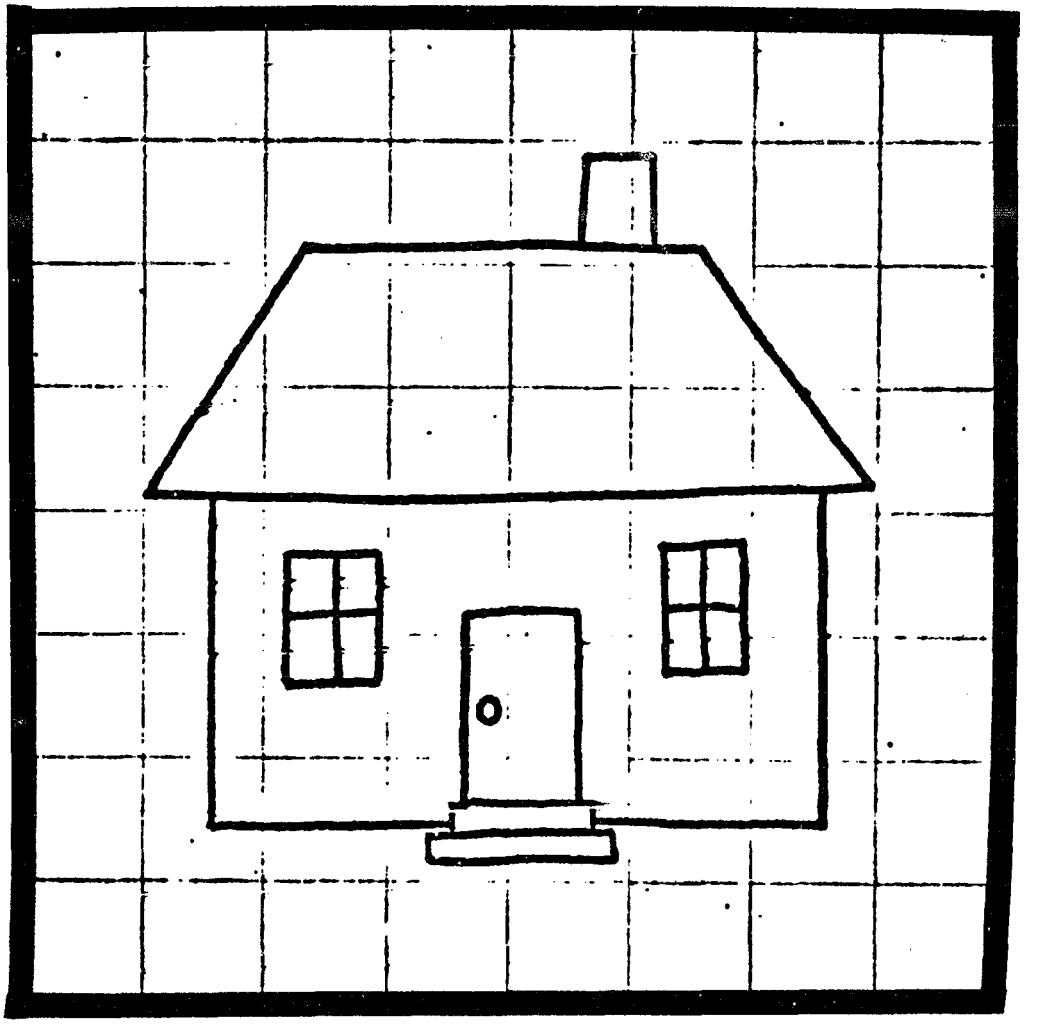
Wohlwill, J. F. From perception to inference: a dimension of cognitive development. In Kessen W. & Kuhlman (Eds) Thought in the young child . Monog. Soc. Res. Child Develpm., 1962, 27, No. 2. pp. 87-112.

Yarbus, A. L. Eye movements and vision. New York: Plenum Press, 1967.

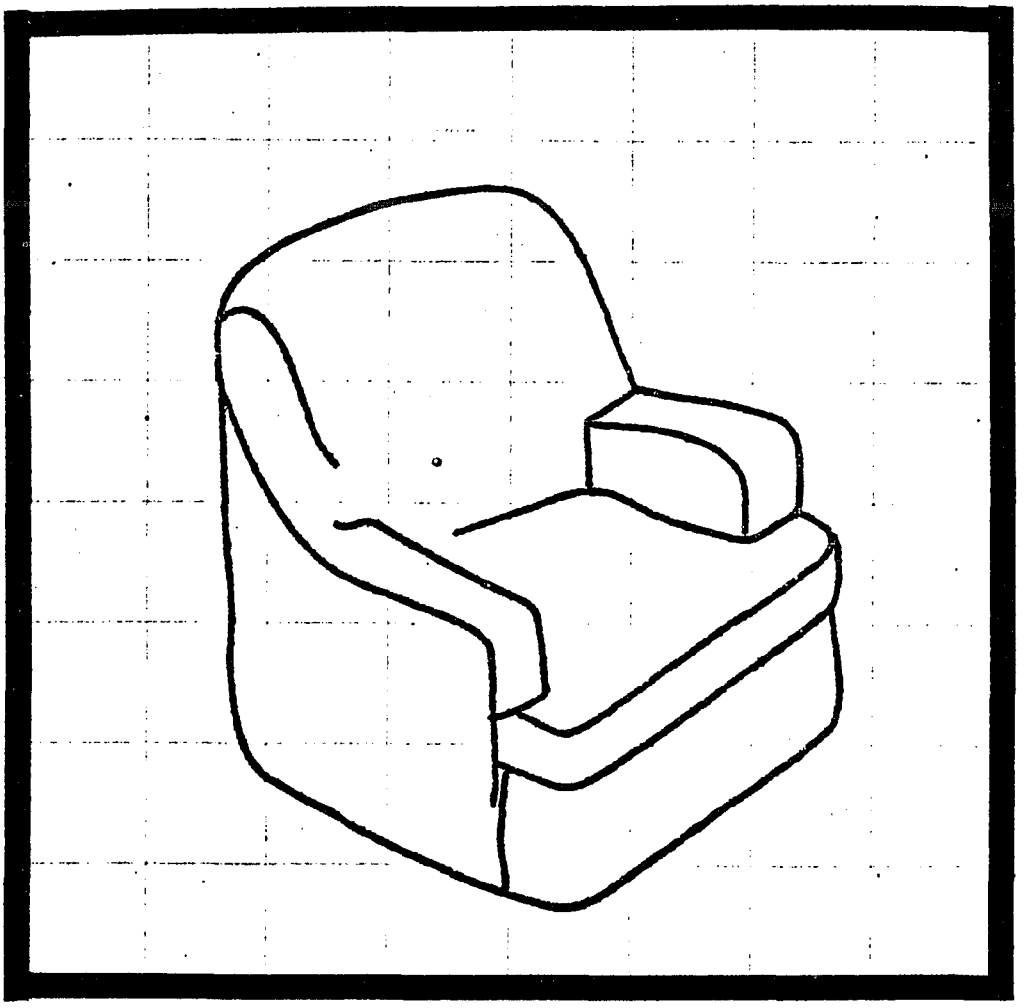
Zusne, L. & Michels, K.M. Nonrepresentational shapes and eye movements. Percept. mot. Skills., 1964, 18, 11-20.

APPENDIX

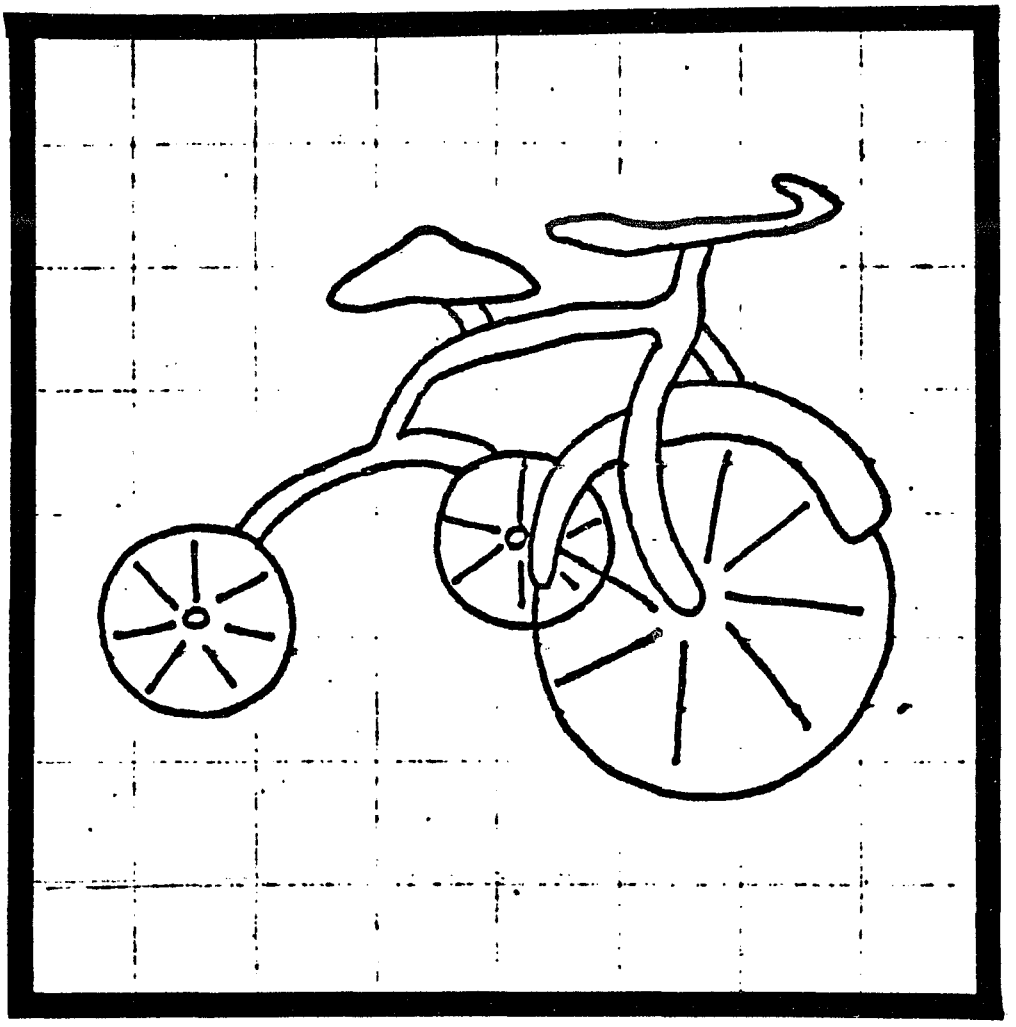
Copies of the ten pictures used in the experiments



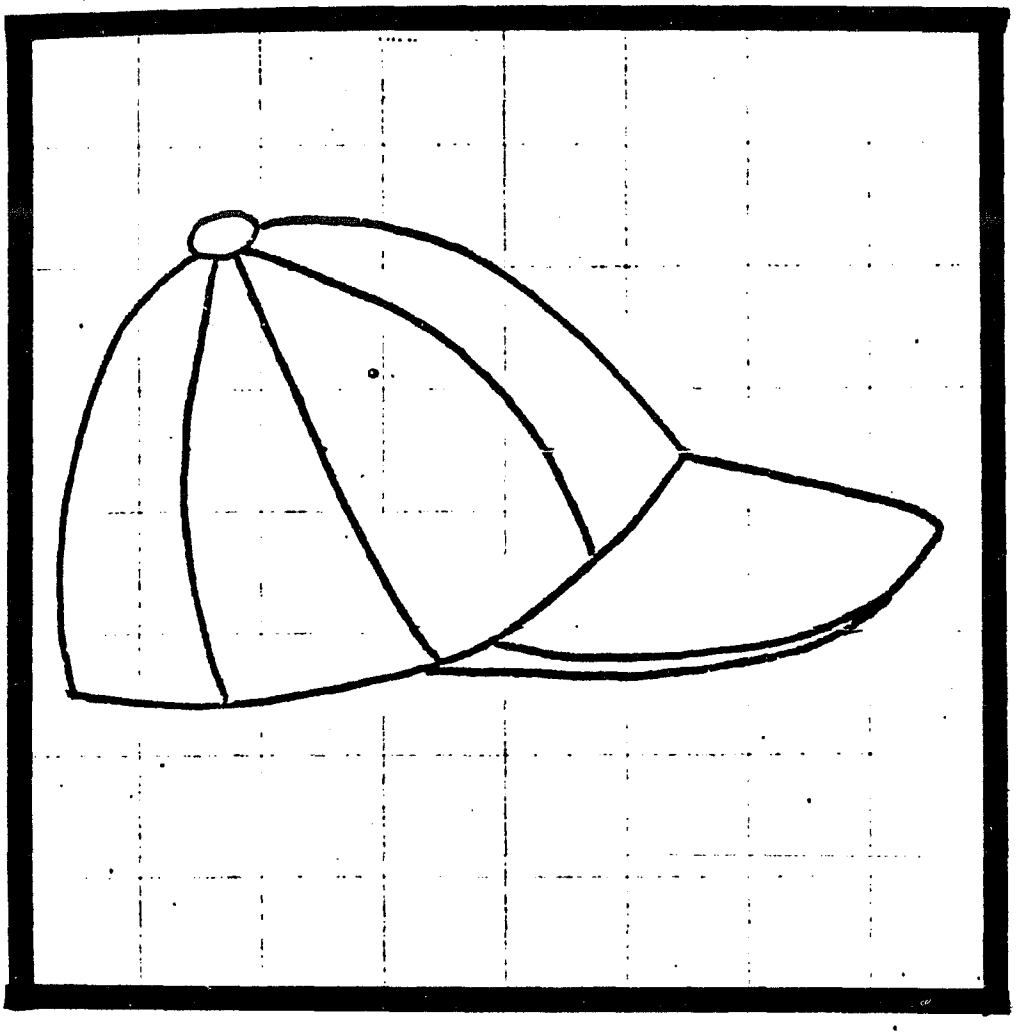
HOUSE



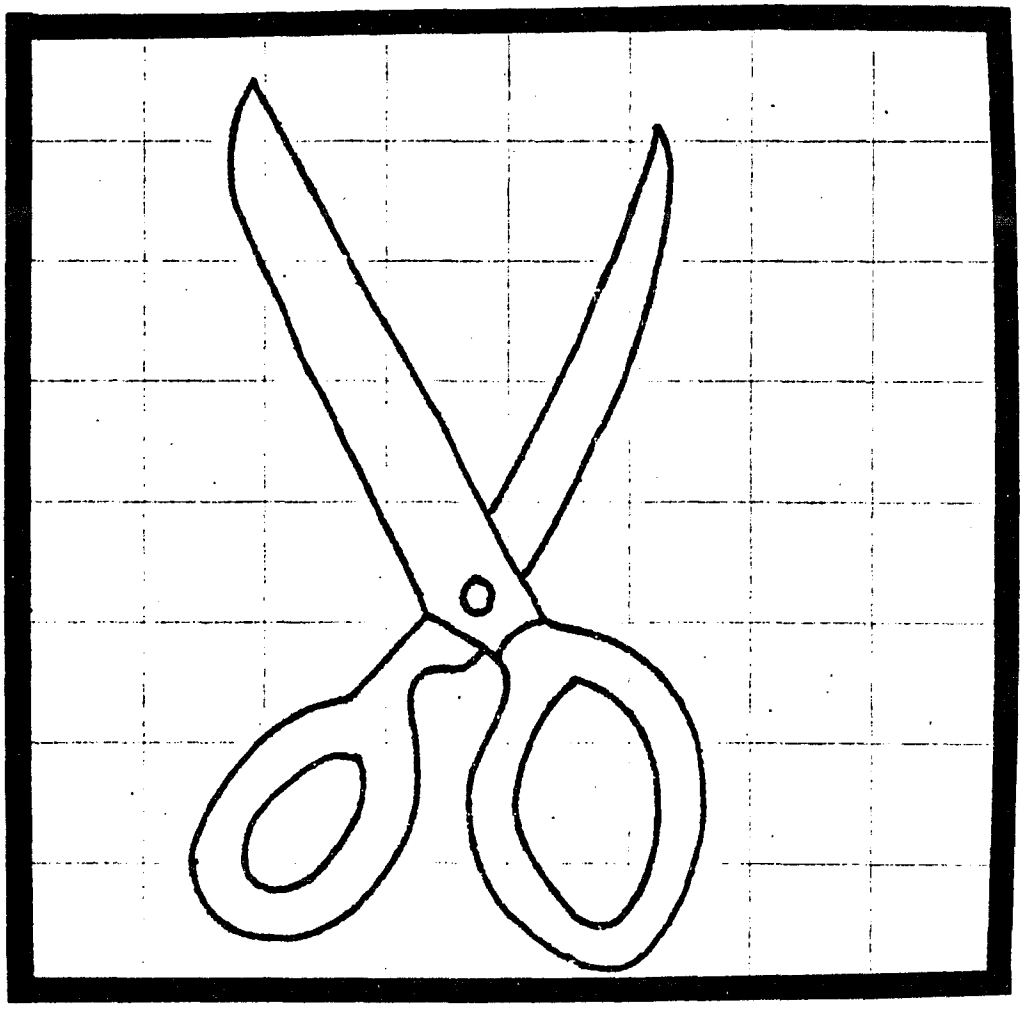
CHAIR



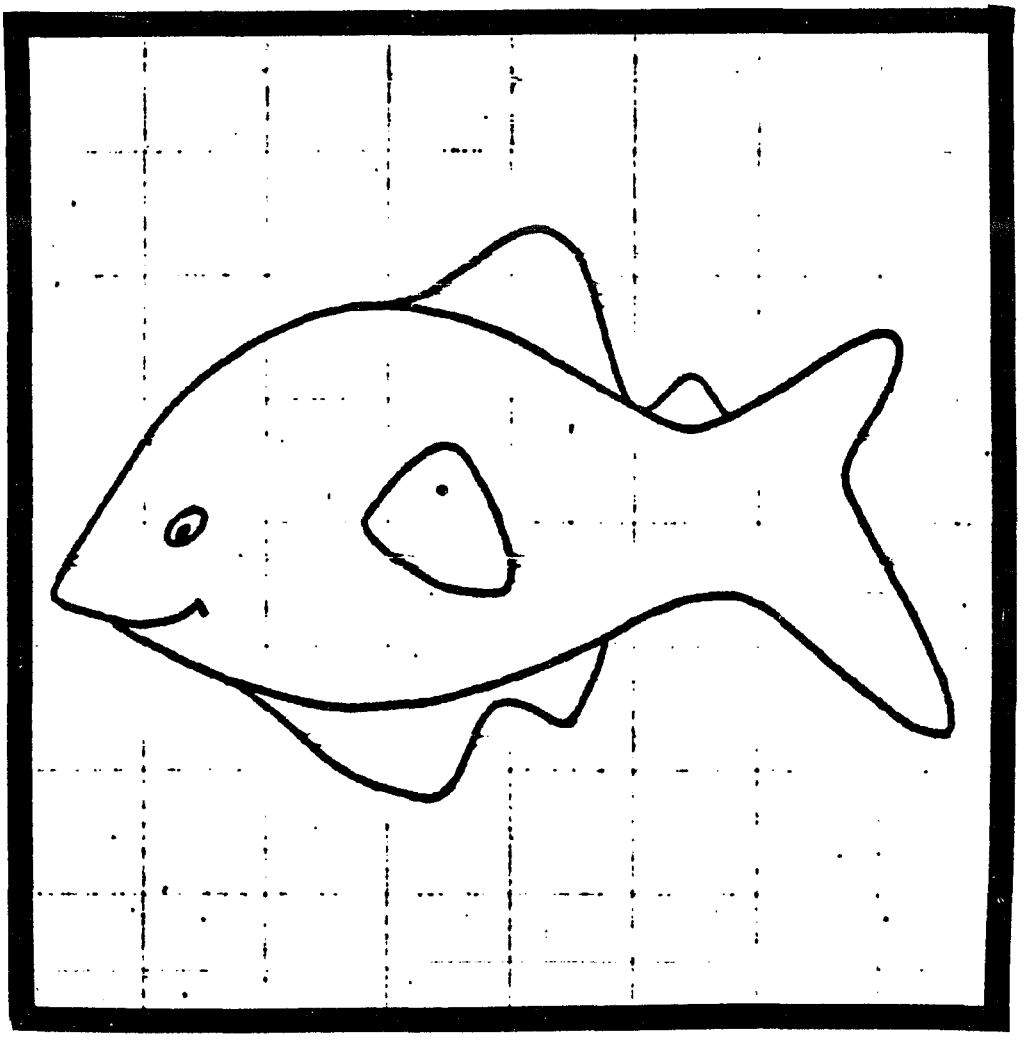
TRICYCLE



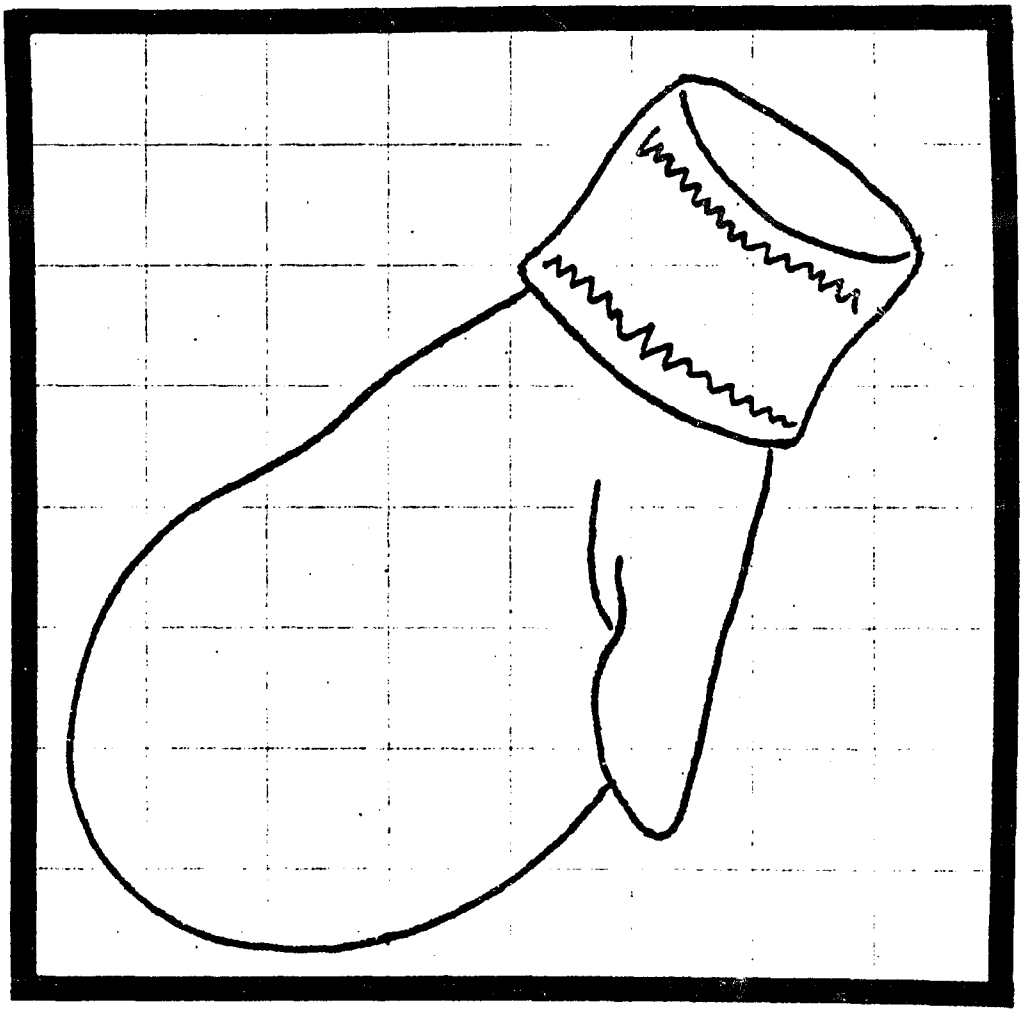
CAP



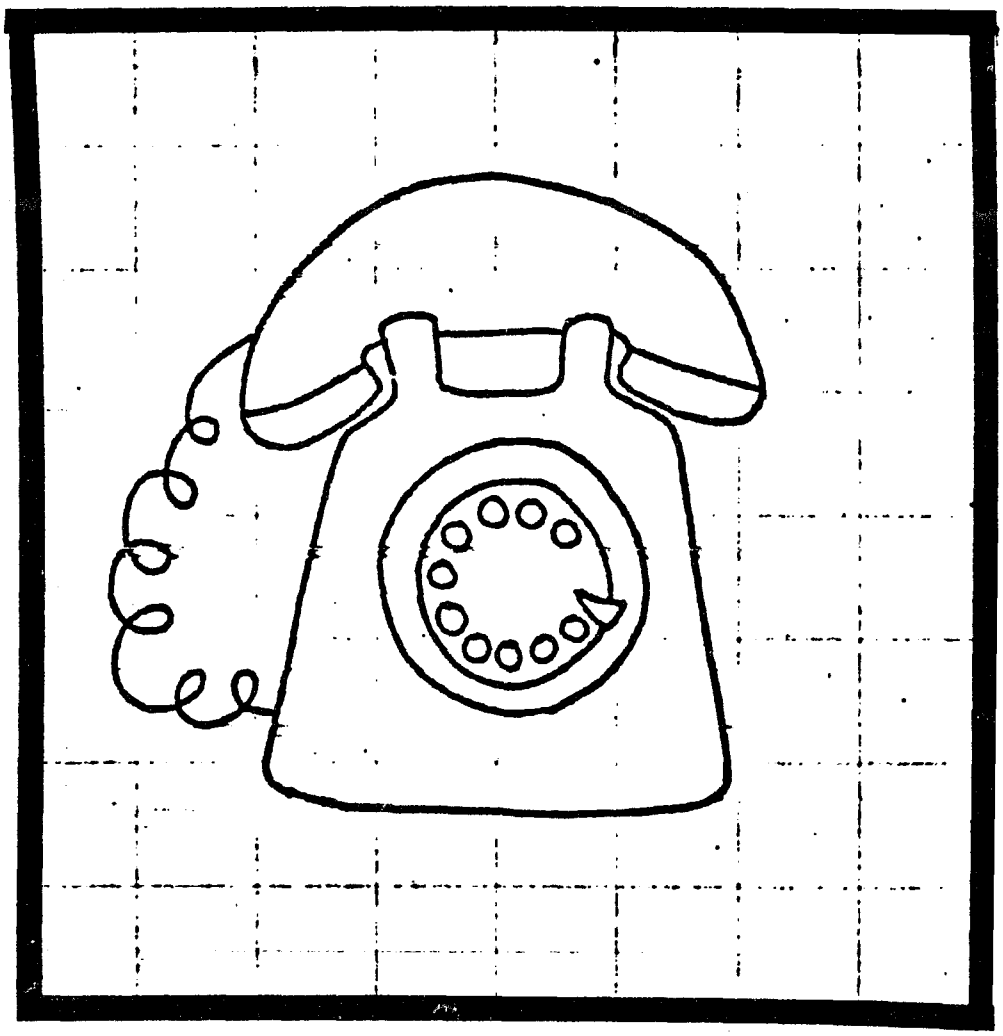
SCISSORS



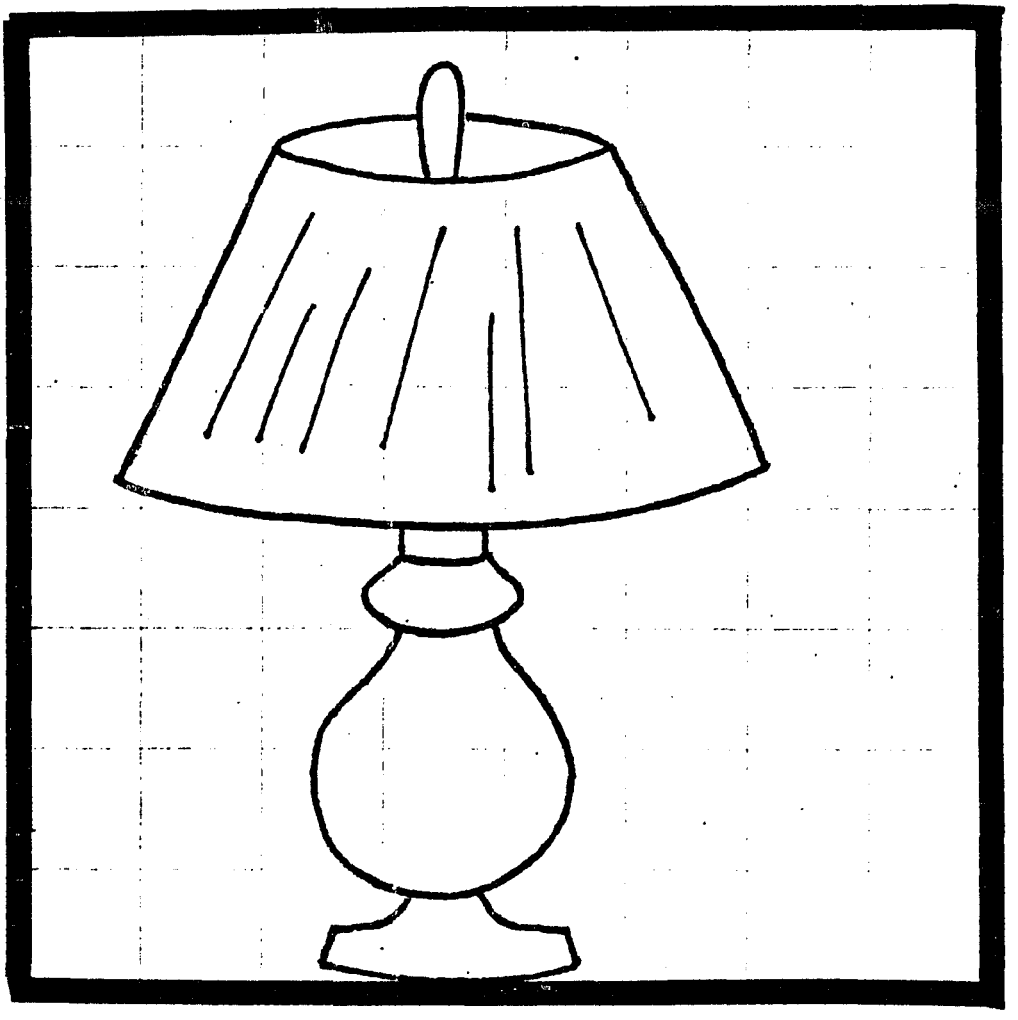
FISH



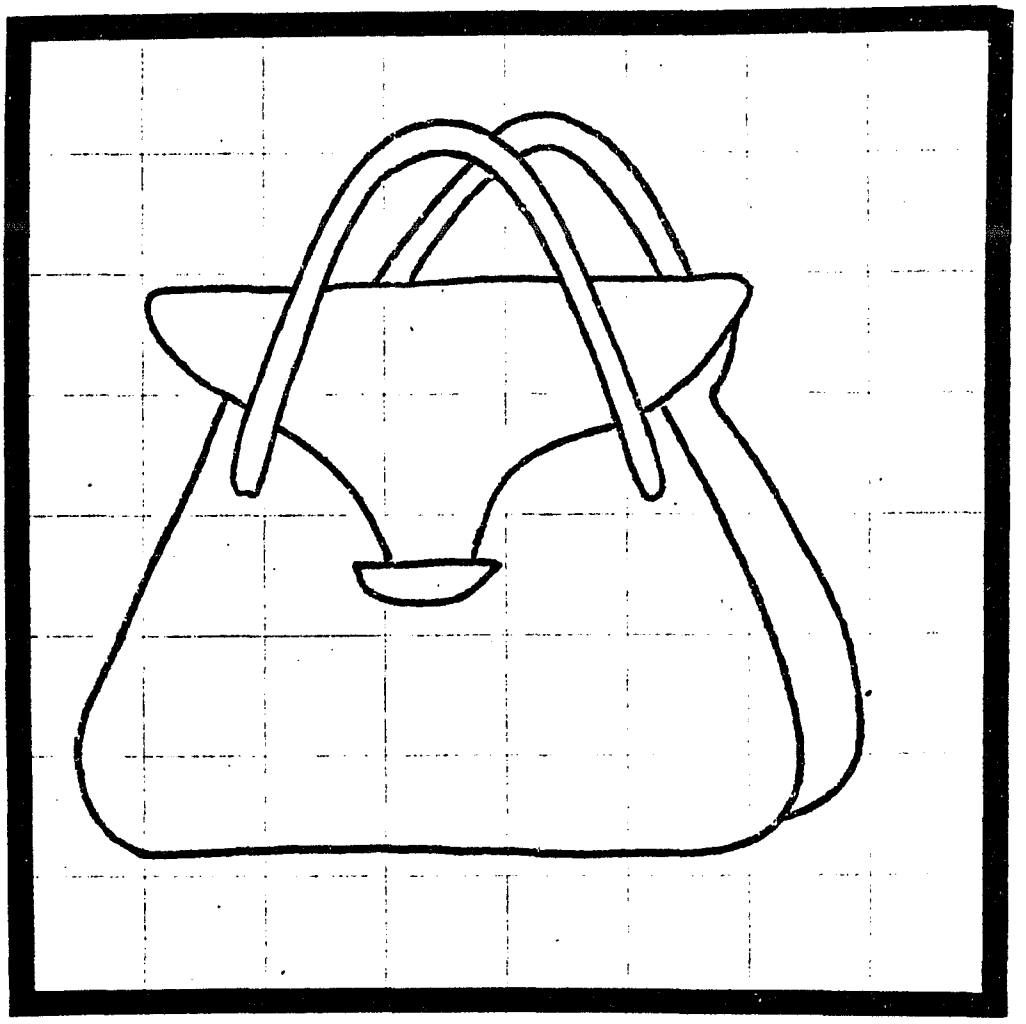
MITTEN



TELEPHONE



LAMP



POCKETBOOK