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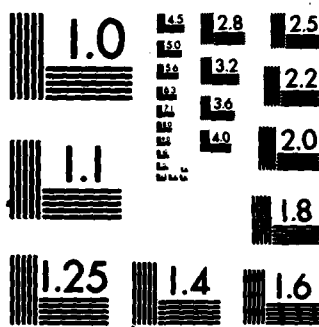
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METHODOLOGICAL ISSUES IN RESEARCH ON READING TEXT WITH ILLUSTRATIONS--ETC(U)
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Finally, important research questions are presented as foci for future investigations.

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Abstract

This report presents a critical review of past research which investigated the effects of illustration on readers' comprehension of instructional materials. The review includes a discussion of serious flaws in this body of research, and stresses the need for precise specification of the information content of both pictures and text.

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Methodological Issues in Research on
Reading Text with Illustrations

Introduction

This report is divided into four major sections. The first gives a critical review of past studies investigating the effects of illustrations on readers' comprehension of instructional materials. This section includes a discussion of serious flaws in this body of research and stresses the need for precise specification of the information content of both pictures and text.

Section two places research on "picture-text amalgams" (Hochberg, 1968) into a broader theoretical perspective. Schema theories of reading comprehension (Rumelhart, 1977) and a differentiation theory of reading comprehension (Gibson and Levin, 1975) are briefly reviewed, along with selected related research. Two variables of critical importance to picture-text research which are stressed in this section are: 1) the degree of redundancy between the semantic content of pictures and text, and 2) the relationship between the organization of concepts expressed in text and the organization of concepts found in accompanying illustrations.

The third section gives a detailed description of a method of discourse analysis which we have adapted and are using in current research to control critical variables here identified in the literature review and the discussion of theoretical perspectives. This method is based on the work of Carl Frederiksen (1975) and provides a means for specifying the semantic content of picture and text stimulus materials.

Finally, section four contains a discussion of research questions which may be tractable using the methodology described here and which serve to focus investigations involving pictures and texts.

I. Review of the Literature

The cognitive processes involved in extracting information from textual materials have long been the subject of research in education and psychology. The majority of such studies have focused on the reading process exclusively and have not, for the most part, addressed the relationship between pictures and text as conveyors of information. Thus, the direct application of previous research findings to many types of instructional materials is difficult since most textbooks, as well as technical manuals, provide information in the form of graphics and text.

One particular area where few studies are found to exist is in the use of pictures as adjuncts to technical instructions. This is somewhat surprising in light of the large number of illustrated procedural materials in use. Nonetheless, of the relatively small

body of research that has studied "picture-text amalgams" (Hochberg, 1968), most has been done with narrative materials and has focused on the question of whether illustrations enhance or detract from comprehension of stories in basal readers.

W. A. Miller (1938) reported that children's comprehension of stories was just as good with pictures as without them. Children of equal reading ability were divided into two groups. One group read stories from a primer with pictures; the other group read the same primer stories without pictures. In various measures of comprehension, there were no significant differences.

Strang (1941) found that individual scores on a test designed to measure comprehension of text presented with or without pictures were consistently higher for the text accompanied by the illustration condition. One concern in Strang's study is the fact that he failed to control for the order of presentation effects. The illustrated condition always succeeded the non-illustrated condition.

Vernon did two studies (1953, 1954) which found that an illustrated version of written text was neither remembered nor comprehended better than a non-illustrated version.

Another study which examined the effect of pictures on the comprehension of a second grade basal reader was conducted by Weintraub (1966). Second grade children in this study scored better in this study when pictures were covered than when both pictures and text were used.

Koenke (1968) attempted to determine whether statements of the

main idea of a paragraph made by elementary school children could be enhanced if a content relevant picture accompanied the paragraph or if simplification of the paragraph was undertaken. Results indicated that the addition of these pictures did not enhance either third or sixth graders' main idea statements.

Lindseth (1969) found that using only the pictures in reading books, and not the text, was not sufficient for children to answer comprehension questions. Lesgold, DeGood and Levin (1976) found that illustrations facilitated prose learning for first graders; and Findahl (1971), using adults, found that pictures improved memory for news items. Denburg (1976) found that, for the beginning reader, pictures facilitated both word identification in context and word learning.

Other studies are also of interest. Fries et al. (1965), Chall (1967) and Samuels (1970) argue that pictures distract the reader away from the content of the text. MacKinnon (1959) and Gombrich (1972) claim pictures present ambiguous and/or misleading information. Vernon (1953), Samuels (1970), Gombrich (1972), Kennedy (1974) and Richards (1974) recommend pictures because they arouse children's attention and motivate them to read.

Two recent studies have examined the manner in which pictures and text communicate procedural information (directions). Stone and Glock (1981) examined the effects of text and pictures on readers' ability to perform an assembly task while reading the directions. In comparing the performance of subjects who read text, text with

pictures, or pictures alone, the optimal performance was found to be in the picture-text condition. Up to this point, most studies had employed a text and text with picture condition and had, therefore, failed to isolate the effect of the pictures alone.

Crandell (1979), also recognizing this difficulty, employed several conditions in the investigation of the effects of educational cognitive style and media format on reading directions. Crandell's study employed a 5 x 5 factorial design with five levels of cognitive style (individual preference for ways of organizing information) and five levels of media format: text alone, text with segmented pictures, text with a composite picture, segmented pictures alone, and a composite picture alone.

Using the same task and similar reading materials as did Stone and Glock (1981), Crandell found no statistically significant interactions between cognitive style and media format. He did find that subjects who viewed segmented pictures alone had the best comprehension of the directions. Crandell's illustrations differ from those used by Stone in that they provided exploded views, used dotted lines to depict the relative position of parts, and also used arrows to indicate action. Crandell also used a community college population in contrast to Stone's use of students in a highly selective university.

A review of those studies which have examined the manner in which text and illustrations complement each other to communicate a message indicates that many of them are seriously flawed. For example:

1. The reading materials used in many of the studies are never identified other than in general terms. (Therefore no replication is possible.)

2. Each of these studies may properly show that a particular picture helps or hinders a child's understanding of a given text (or vice-versa), but it is not possible to generalize from any one of these studies and to make statements about the function of illustrations with text per se.

3. Few of these studies control for the relationship between the content of text and the content of the illustrations. They have not made explicit the concepts or relationships among concepts expressed in text and illustrations. We cannot, therefore, determine whether text and illustrations are completely redundant in terms of content or whether they are only minimally related. We cannot determine the relative contribution made by text and illustrations in communicating the writer's message.

4. None of these studies examines the relationship between the organization of the text and the groupings of concepts as expressed in the accompanying illustrations.

5. These studies vary in terms of the manner in which children's understanding is measured. Perhaps non-verbal as well as verbal measures should be used in order to properly determine what information children have extracted from pictures and text.

6. Finally, few of these studies relate their findings to existing theories of human information processing or other

potentially relevant theoretical perspectives.

In summary, one reason for these conflicting results in this area of research may be the lack of precise descriptions of the textual and pictorial materials used in each study. A clear specification of the information presented in each media format, the relationship between the information in each format, and the verbal or non-verbal nature of the evaluation instrument, may reveal a variety of uncontrolled stimulus variables directly affecting the comprehension process. Hence, any investigation of the comprehension of information presented in materials made up of picture-text combinations must address these areas of concern.

A brief review of several theoretical perspectives and additional related research on the reading process will reinforce the importance of precise specification of textual and pictorial information content.

II. Theoretical Perspectives

Before beginning our consideration of several of the theoretical perspectives pertinent to the study of reading text with pictures, it is appropriate to consider the basic characteristics of text and illustrations at the graphic level.

Gibson and Levin (1975) have defined the graphic characteristics of writing as follows:

1. Writing is formed by tracings on a surface. These tracings may add to the surface, like ink or dye, or like a chisel, can carve

out a tracing.

2. Writing is rectilinear. It is composed of lines of print which are parallel to each other. The parallel lines may be vertical (Chinese) or horizontal. (Writing on statues or engravings which is not rectilinear but follows the contours of the surface does not preclude rectilinearity, but may be thought of as a decorative or artistic variant.)

3. Writing is unidirectional. Current writing systems are predominantly left to right, less frequently, right to left, and only occasionally top to bottom. The starting point for each line is fixed.

4. Writing has a fixed orientation. The elements of the writing system cannot be transformed relative to each other. For example, the letters A B retain their orientations wherever they appear in the text, so that a variation like A  does not occur.

5. Writing is patterned. That is, a small inventory of basic units can be combined to form a practically infinite number of graphic patterns. Graphic distinctive features--vertical, horizontal, diagonal, curved, open-closed, combine to form letters which in turn form clusters, syllables, words, phrases, sentences, paragraphs, etc.

6. Writing has gaps (or spaces) in the graphic display. These gaps mark graphic units. Gibson and Levin advance the hypothesis (which may be limited to the Roman alphabet) that the size of the gap is related to the size of the unit. The smallest gaps separate

letters, larger ones, words, then sentences. The largest are paragraphs, which involve a gap at the end of a line and an indentation at the beginning of the succeeding line. Gaps mark syllables as units in syllabary writing schemes but not in alphabetic ones, though we do have the convention that when words must be separated, as at the ends of lines, the gap occurs at the syllable boundary.

Graphic units may be marked in other ways than by spaces. Hebrew, Arabic, and German have letter forms which occupy terminal positions in words; another form of the letter is used in initial and medial positions. In the writing system Devonagari, used in India, the letters appear to hang from a horizontal line whose length defines the length of the word, so both the line and the spaces mark word boundaries.

7. Written units are roughly equal in size. Different letters occupy the same area and words are more or less similar in size. This makes writing appear regular with more or less equal black and white spaces.

8. Writing has various forms that are not usually mixed. A text may be handwritten, typed, printed, cursive, capitals and lowercase, etc. Not all writing systems have the same variations. Styles are mixed only for conventional reasons, as capitals at the beginning of sentences.

These characteristics define writing systems at the graphic level and, with the exception of item 1, discriminate writing from all

other graphic displays. In contrast, even simple line drawings include so many features in rich and complex combinations that a feature analysis, though feasible, is very difficult. The reason for this is that writing was a deliberate invention, created to be as efficient as possible. Furthermore, writing systems have evolved over the past 5000 years with a historical convergence on a limited set of graphic features that are both highly efficient and virtually universal.

Written discourse may be further differentiated from other graphic displays in that it can be described phonologically, orthographically, and syntactically. It is at the level of semantic analysis, however, that we find that written discourse and other graphic displays may be quite similar. For example, the word "apple" and a picture of an apple may be subjected to a semantic features analysis that results in a sequence of hierarchically arranged taxonomic categories (e.g., apple—fruit—vegetable—edible). Full recognition of a word or picture depends on extraction of these kinds of information which are features of the graphic display.

Pictures are differentiated from written discourse in the ways described above, but they require further description. James Gibson (1954) defined a picture as follows:

"A picture is a surface so treated that a delimited optic array to a point of observation is made available which contains the same kind of information that is found in the ambient optic arrays of an ordinary environment."

The photographer, or artist, fixes a point of observation and reproduces the static visual information essential for identification and location of objects in that scene. The manner in which people perceive the information in pictures appears to be in most respects similar to the way they perceive objects in their normal environment. However, the perception of depth and distance relations in pictures does not seem to occur automatically. This is perhaps due to the presence of surface information which specifies the flat quality of a picture as an object in itself. It may be that the conflict of this information with pictorial depth information cues a compensatory pictorial-processing mode. A further difference between perception of information in the normal environment and that in pictures is that the information in pictures is presented from a static, monocular perspective. In contrast, people in a normal environment obtain perspective information as they move about and experience lawful variations in the optic array. (Pick, 1973)

One natural consequence of the basic differences between text and pictures at the graphic level is that the reader of text must accept the writer's organizational format for the concept expressed in the text. Although readers sometimes skip over or skim text, they usually read in a conventional linear pattern.

By contrast, the reader who looks at a picture is free to sample the information presented there in any way he or she sees fit, although there is some evidence that pictures do present semantic information in organized ways and that readers view these displays in

ways that reflect a hierarchical structure of information content (Loftus, 1976).

Eye-track data, to the extent that such data reflects cognitive events, may provide some insight into this question. Although much research of this kind has been done with text or with pictures, little has apparently been done using both pictures and text.

Loftus (1976) views the process of encoding information in graphics as consisting of three stages.

Stage 1 - Decision about where to look in the picture.

Stage 2 - Once a particular area has been fixated, information from this area must be extracted and processed during the fixation, and

Stage 3 - The information extracted during a series of fixations must be integrated into some overall representations.

Loftus reports research that supports the view that readers obtain what is referred to as "gist" information about the graphic within the first one or two eye fixations. Gist information is simply information that permits the readers to say what the graphic represents in some general way (i.e., a picture of a horse vs. a picture of a lion).

Next it appears that readers fixate on what are referred to as information areas in the graphic. Such areas are defined by Mackworth as areas reported by subjects to be informative while Berlyne (1950) defines these areas in terms of their complexity and novelty. (For example, subjects viewing a city skyline would find

the outline of a very tall building to be informative as opposed, say, to the information provided by an area of clear sky.)

Stone (1978) reports research that indicates that readers who view text/graphic combinations appear to spend the first second or two obtaining gist information from the graphic. Readers then tend to refer to the text and to read for several seconds. They then refer periodically to the graphic, seemingly for edification of information presented in the text. It is surmised that these referrals from text to graphic are made to high information areas that are either redundant of the information content of the text, which complement the information content of the text, or which provide an organizational structure for the text content.

One difficulty in attempting to apply eye-track technology to this area of study is that it is more difficult to specify the information available to the eye at a given fixation when the display is pictorial than when it consists of text. When the eye fixates on a letter of a word we may assume (with some justification) that the graphic, orthographic, phonological, syntactic, and semantic information contained in the word is available to the reader (if it is a word in the reader's vocabulary). However, if the reader fixates on a portion of a picture it is much less clear what information is available to the reader at that point due to the complexity of the graphic features of the display.

Given the on-line computer controlled eye-track technology available at present, it should be possible in the near future to record eye-movements as people read combinations of text and pictures and to subsequently specify what information they extracted from each source, the sequence in which they extracted it (i.e., how they combined information presented in text and pictures) and perhaps identify specific factors that cause the reader to refer from text to picture or vice-versa. (For example, if a particular type of information is more clearly depicted pictorially, subjects might consistently refer to the picture for that kind of information.)

Now that we have reviewed the literature dealing specifically with the question of how people read and understand information presented to them in pictures and text and have considered some basic similarities and differences in these means of expression, let us examine several theoretical perspectives and related research that may be of value in considering this issue in greater depth.

The theories to be reviewed here include schema theories of comprehension (Rumelhart, 1977), a differentiation theory (Gibson and Levin, 1975), a dual processing model (Paivio, 1974, 1977), and a model of knowledge structure (Frederiksen, 1975).

Before exploring these models it is important to recognize that there can probably be no single model for reading. Gibson and Levin (1975) point out that the skilled reader is very selective. He or she skims, skips or concentrates, planning ahead and adapting reading strategy to his or her interests, the material to be read, and the

purpose for reading. The reader does not perform some pure process of decoding and comprehending, he thinks, he remembers, and he constantly relates what he sees to what he has seen before, what will come next and to his own experience. There can therefore be no single model of the reading process.

Even so, the theories reviewed here are thought to provide a useful perspective on the manner in which people read pictures and text.

Rumelhart (1977) presents a model of the reading process in which readers generate hypotheses at a variety of levels designed to account for portions of the incoming information. Levels of hypotheses would include the letter-level, the lexical-level, syntactic-level, and semantic-level. Hypotheses at an even higher level are proposed which account for entire stories. These hypotheses are called schemata. Such schemata provide a context for incoming information, predicting (and inferring) the existence of lower level hypotheses.

Rumelhart cites several studies by Bransford and Johnson (1973) to show how important schemata are in reading comprehension. An illustration may cause the reader to generate such a high level hypothesis. The accompanying text may be almost meaningless without such a frame of reference as is shown in the "balloon passage."

If the balloons popped the sound wouldn't be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady

flow of electricity, a break in the middle of the wire would also cause problems. Of course the fellow could shout, but the human voice is not strong enough to carry that far. An additional problem is that a string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems with face-to-face contact, the least number of things could go wrong.

Subjects who read this passage without the illustration found it to be almost incomprehensible. Those who were allowed to view the illustration for 30 seconds prior to reading the passage found it entirely comprehensible and could recall over twice as much of the story as those without the illustration.

--Insert Figure 1 about here--

As Bransford and Johnson point out, context may be provided by text as well as by illustrations. However, illustrations may be of particular value when they provide such a frame of reference.

Gibson and Levin (1975) have provided a theoretical basis for understanding how people read pictures and text. They view the process of reading as one of extracting information from pictures and text. They believe that "higher order structures" are basic to perceiving patterns of distinctive features in pictures and text. These structures are seen as rule systems that describe subordinate relationships among the phonological, syntactic, and semantic components involved in reading. The key processes involved in developing such rule systems include abstracting relationships, ignoring irrelevant information, locating potential information

areas, using distinctive features, and obtaining intrinsic reinforcement through the discovery of structure and the reduction of uncertainty.

An experiment by Mackworth (1972) is cited by Gibson and Levin (1975) to show that the failure to comprehend written text does not necessarily coincide with failure to extract meaning. "Children known to be poor readers were shown a complex picture which was then withdrawn, and another presented which was the counterpart except for a single change in one area. The child was required to point to the area that was changed. The children tested ranged from kindergarten through third grade; there was absolutely no difference between good and poor readers. Poor readers, however, took longer to match words with pictures."

A study by Peeck (1974) is one of the few in the literature to attempt to control for the relationship between the content of text and the content of illustrations used with the text. Peeck used pictures selected to convey information in an accompanying story. In a cartoon format, Peeck varied the agreement between the information contained in the pictures and that contained in the text. When the same information was presented in both the pictures and the text, fourth grade children who read the illustrated text scored higher on questions assessing knowledge of information when compared to children who read only the text.

For children reading illustrated text, points of conflict between picture and text resulted in the selection of the picture information

responses for information contained only in the text, there was no difference in retention between groups reading illustrated and non-illustrated versions of the text.

The Peeck study suggests that the degree of correspondence between the semantic content of illustration and text is an important variable affecting comprehension and recall.

In summary, Rumelhart, Bransford, and Johnson; Gibson and Levin, and Peeck have provided theories of potentially great significance for the study of how people read and comprehend information presented in pictures and text and have identified variables crucial to the study of this issue. To recapitulate, the variables are:

1. The degree of redundancy between the semantic content expressed in pictures and text.
2. The relationship between the organization of the concepts expressed in text and that found in accompanying illustrations.

Paivio's (1978) theory of a dual coding approach to perception and cognition makes a distinction between two types of information, communicative and environmental. The theory is based on three assumptions: the first is that two distinct symbolic systems are involved in perception, memory, language and thought. One system is specialized for processing non-verbal information (referred to as the imagery system). The other system is specialized for processing linguistic information (referred to as the verbal system).

The second assumption is that the two systems are functionally independent, but partially interconnected.

A third major assumption is that long-term memory and perception use the same systems. Perception and memory are thought to be continuous. The functional representations of the non-verbal system (drawings, imagery, etc.) are thought to be analogous and continuous in nature, and are highly isomorphic with perceptual information. Paivio, therefore, asserts that environmental information is represented in long-term memory basically in perceptual form.

He asserts that the units of the verbal system are discrete linguistic entities which are arbitrarily related to perceptual information. He claims that "the linguistic system per se does not contain the perceptual or semantic information that corresponds to our knowledge of the world, or as Pick puts it 'environmental information.' Instead the verbal system can retrieve such information only by probing the non-verbal representational system."

Further, it is said that the non-verbal system is activated more directly by non-verbal objects than by linguistic stimuli. Conversely, the verbal system is activated more directly by spoken or written language.

Finally, the perceptual information in long-term memory can be used for various purposes, depending on task demands, including descriptions of the environment, making inferences, and active transformations of the symbolic information (see experiments by Piaget and Inhelder (1966) and Cooper and Shepard (1973)).

Paivio asserts that this theory can better account for differences in memory reactions to pictures and words and for

perceptual memory transformations (of the kind that Cooper and Shepard (1973) have explored), than can theories based on a common representational system for both kinds of information (Norman and Rumelhart, 1975; Anderson and Bower, 1973).

Frederiksen's (1975) paper "Representing Logical and Semantic Structure of Knowledge Acquired from Discourse" attempts to present an explicit model of knowledge structure. This model is defined entirely without reference to linguistic structures and is capable of representing the informational structure of nonlinguistic "messages" such as visual arrays and experienced events as well as that coded in linguistic messages. Its locative relation, for example, specifies the two- and three-dimensional properties of space that linguistic deep structure could not represent.

Frederiksen has not only attempted to present an explicit model of knowledge structure, but has also attempted to provide a procedure for coding logical and semantic information acquired from text based on the logical and semantic structures he presents in the model.

This procedure is advanced as a means of assessing subjects' memory structures for text, either by providing a basis for systematically probing subjects' memories for text, or as a reference structure against which subjects' text recalls (or other verbal responses) could be scored. It would then be possible to assess precisely what semantic information a subject has acquired from a text and to specify what relationship obtains between semantic information acquired from a text and the semantic information from

which the text was derived. Thus, by comparing a subject's memory structure for a text (as inferred from his responses to probes on text recall) to the logical and semantic structure from which the text was generated, it is possible to begin to reconstruct the processing operations which a subject applied to the input text to generate his memory structure for the text. In this manner, one can begin to determine precisely what logical and semantic knowledge is acquired when a text is "understood," to specify the processes by which such knowledge is acquired, and by systematically constructing texts from specified semantic and logical structures, to study effects of structural characteristics of text on these processes.

Frederiksen's model represents both "semantic structures" consisting of propositions which are represented as networks of concepts connected by labelled binary relations and which identify events or states, and "logical structures" consisting of networks of propositions which are connected by various labelled logical, causal and algebraic relations.

As Frederiksen points out, semantic structures have recently come to be regarded as central to linguistic descriptions of natural language. Generative semanticists such as McCawley (1968) and Lakoff (1971) argue that there is no formal difference between syntactic and semantic rules; rather there are only semantic representations and grammatical transformations that relate them to surface structures (sentences). They hold that it is more parsimonious to adopt a system of grammar which starts with logical predicates and contains

rules for mapping these propositions directly onto surface sentences. Frederiksen has adopted this approach.

Furthermore, many linguists, Grimes (1975) and others, have come to emphasize discourse rather than the sentence as the unit of analysis. These linguists have pointed out that certain derivations of a sentence may be judged to be ill-formed in one context and grammatical in another. People make judgments concerning grammaticality based on the context of the written sentence or spoken utterance. Any linguistic theory which ignores context must therefore be judged to be inadequate.

In light of these observations, Frederiksen has attempted to make his model sensitive to: (1) the conceptual context of an utterance; the presuppositions (beliefs or intentions) held by a speaker at the time of an utterance, (2) the extra-linguistic context; the time, place, and location of speaker and hearer, and (3) the linguistic context; the context given by previous discourse within which a sentence is embedded.

Frederiksen advances a conception of linguistic production which he argues is a more plausible basis for a psychological model than was Chomsky's system of grammar. First, the basis for linguistic productions is semantic (propositional) structures. Second, grammatical rules are being formulated at the discourse level, relative to discourse context, extra-linguistic context, and conceptual context. Third, grammatical rules are being formulated as transformations which map directly from semantic structures to

surface sentences. Frederiksen's model, therefore includes a linguistic description of text encompassing a semantic structure and a set of grammatical rules which generate texts from semantic structures.

III. Specifying the Semantic Content of Picture and Text Stimulus

Professor George McConkie has been instrumental in transforming Frederiksen's model into an effective research instrument for gaining knowledge about the way people learn from text. (Dee-Lucas, 1978) McConkie and his colleagues have been asking questions about the nature of the language processes involved in comprehending text, the nature of the cognitive representation which is established to represent its meaning, the basis on which the person selects some information rather than other to retain, how information in the passage is integrated with related prior knowledge and how it is affected by the acquisition of later knowledge, how stored information is later retrieved, the nature of the processes involved in making use of that knowledge for the purpose of the task used in assessment, etc.

McConkie and his colleagues have transformed Frederiksen's model into an effective system for representing the content structure level of the text. They then use free recall and probe measures to determine what readers remember after having read the passage. These recalls are submitted to an analysis of their content and logical

structure in the same manner as the original passages. Once a set of free recalls of a passage have been analyzed and scored, the resulting data can be examined in many different ways. For example, it is possible to work with recall frequencies of individual elements or propositions, with dependency relations among elements or propositions, with the sequence in which propositions are mentioned in recall, with the ways in which the free recall is modified from the original passage, with intruded information not present in the passage, and so on. These data are said to bear on such diverse questions as whether structural characteristics of the form in content influence the reliability of segments of the passage, whether there are high-level macro-structures which guide the person to recall the elements of a passage in a particular sequence, and what meaning the subjects seem to store from a segment of text, which may be inferable from the variety of ways in which that information is actually expressed in the free recalls.

Studies employing this approach are reported by Marshall and Glock (1978), Clements (1976), Lucas (1977), Dee-Lucas (1977) and Smith (1977).

These studies have dealt exclusively with text, but provide useful examples of the application of Frederiksen's system to the solution of research problems.

Stone (1978) reports an application of the same methodology to an investigation of the communication of procedural information in a variety of forms of pictures and text. This research, conducted in

cooperation with Professor Marvin D. Glock of Cornell University has developed a methodology that permits an objective specification of the logical and semantic content of pictures at the content structure level. The procedure involves asking subjects to view the illustrations and either describe them orally or in writing. These descriptions are then subjected to an analysis (McConkie) which transforms them into a set of propositions. Scorers then compare these sets of propositions to arrive at a common, objective representation.

Given an objective specification of the logical and semantic content of both text and illustration it is possible to closely control for the relationship between the concepts and relations among concepts when pictures and texts are presented together. For instance, text and pictures may be constructed so that the concepts in each are identical or so that they complement each other. Similarly, manipulations of form may be performed in a comparable manner on both text and pictures. For example, in a procedural text with pictures, the sequential, referential or spatial content of both pictures and text may be emphasized without affecting their semantic content.

Recall by subject may be in the form of a free written recall, performance of the task specified in the procedural directions (recorded on videotape), or through verbal or pictorial probes. Recalls of whatever type can be represented in the same propositional format and can be subjected to the sort of analyses proposed by

McConkie.

Current research employing this approach is directed towards an evaluation of the effectiveness of different forms of text and picture presentations in communicating procedural information to readers.

Now let us examine the system's characteristics in greater detail. The essence of the system is the idea that a passage of text or an illustration can be viewed as presenting a number of different concepts generally classifiable as objects, actions, or attributes. Text expresses the relationships among these concepts through the use of sentences while an illustration expresses such relations graphically. The passage of text or illustration can therefore be represented as a form of network structure with the concepts being the points or nodes in the structure, and the relations being represented by the lines between the nodes. In practice, a linear representation of this network structure is used. The logical and semantic structure of text, illustration, as well as verbal or non-verbal recalls, are represented by a series of numbered propositions. (For example, an object, - John - may be either the one who performs an action, - hit - or the one who is the object of the action, the one being hit. The label on the line is therefore either object or agent to make the necessary distinction.) (McConkie, 1977).

In order to determine the content of a text or graphic that is transformed by scorers into a series of propositions expressed as a

network structure, let us consider another example from McConkie (1977). "John hit the red ball" - is represented by two propositions: "The ball was red"

P1: (:Ball)—att—(red)

att = attribute

and - "John hit the ball" -

P2: (:John)—agt—(hit)—obj—(:Ball)

agt = agent, obj = object

Words representing the concepts mentioned are placed in parentheses, and the labels on the relationships are embedded in the arrows which represent these relationships. Each proposition is numbered.

--Insert Figure 2 about here--

Figure 2 shows a sample of a procedural text used by Stone and Glock (1981) consisting of the directions for the assembly of a model. After each section of the directions there appears a list of the propositions which represent the logical and semantic content of that portion of the text. Illustrations designed to depict the identical content are shown in Figure 3.

--Insert Figure 3 About Here--

Within the context of the task environment it is asserted that the content and logical structure of both illustrations and text are directly comparable. This comparability was arrived at by employing the following procedure:

First, a set of written (i.e., text) instructions was produced. These instructions were pilot tested on several individuals to assess their clarity and completeness for accurate construction of the model. Next, pictures were designed by an artist following the text directions. These pictures were intended to be semantically redundant with respect to the text. Finally, the pictures alone were then pilot tested to assess their independence from the text as complete and accurate conveyors of the necessary assembly instructions. These procedures were described by Stone (1977). At this point, text and illustrations were each known to contain all necessary and sufficient information for the accurate performance of the assembly task. However, the specific semantic content of each remained unspecified.

In order to specify the semantic content of both text and pictures in comparable terms the text instructions were coded into an ordered list of propositions based on the modified Frederiksen system (Dee-Lucas, 1978). Next, the pictorial instructions were given to volunteers who provided written descriptions of the picture. These written descriptions were also coded into an ordered list of

propositions using the modified Frederiksen model. The two lists of propositions were compared and several modifications were made to both text and pictures. After validation by pilot testing, it was felt that a "core" of redundant information was present in both pictures and text, which was describable in a comparable manner, and which was necessary and sufficient for successful completion of the assembly task.

The use of this system permits the researcher to control for the relationship between the content of text and illustration. The concepts and relations in each are made explicit and the relative contribution of text and illustration in the communication process can therefore be examined. The organizational value of each may also be assessed, since the system captures the logical structure of context expressed in text or illustration. This system can be used to make explicit the semantic content and organizational structure of what people recall (either verbally or non-verbally) after reading a passage. Thus, the content of the original text and illustrations may be compared with what readers recall in equivalent terms.

IV. Suggested Research Questions Involving Pictures and Text

A review of these studies leads to some specific suggestions for the design of an improved series of experiments in this area.

The general question as to whether pictures help people understand text may be answerable only in terms of specific types of illustrations and specific functions. The differential utility of

illustrations or text may vary with the type of information, the information structure or logical relationship to be communicated. (For example, it may be found that illustrations are uniformly more helpful for understanding spatial relationships than is text.)

In order for such questions to be addressed it will be necessary to overcome each of the deficiencies noted in the studies cited earlier.

1. Studies in this area must clearly specify what texts and illustrations have been used so that other researchers can replicate them.
2. Studies are needed which examine the effects of different forms of illustration (line drawings, color photographs, motion pictures, slides, etc.) on texts (and vice versa) so that results are generalizable beyond a particular set of reading materials.
3. Scoring systems need to be developed that allow researchers to identify and compare in equivalent terms the semantic features present in illustrations and text, thereby permitting control for semantic content.
4. Scoring systems sensitive to the organizational structure of both illustrations and text need to be developed so that the effects of text organization on comprehension of picture content may be assessed (and vice versa).
5. Finally, non-verbal and verbal measures of comprehension should be employed to determine how differences in measurement affect assessment of comprehension of the content of pictures and text.

Among the questions that our research group hopes to address are the following:

1. In order to specify more thoroughly the semantic content of procedural instructions, it would be helpful to develop a taxonomy of the categories of information conveyed by such instructions.

(a) What categories of information characterize procedural instructions?

(b) How can the categories of information from (a) be depicted most efficiently in text and pictures?

(c) How do these categories of information differ among various kinds of procedural tasks? (e.g., assembly tasks, as opposed to the tasks performed by Navy S3-A TACCOS and SENSOS during ASW operations).

(d) Can different types of tasks be classified according to the structure of the semantic content and the categories of information to be communicated in the instructions for those tasks?

2. Manipulation of the semantic content of textual and pictorial portions of procedural instructions may be helpful in explaining the cognitive processes involved in executing procedures.

(a) How do variations in the semantic content of pictures affect the text processing load, and vice versa?

(b) How do variations in the redundancy of procedural texts and pictures (by information type) affect the representation of procedural information in memory?

3. One of the problems in developing procedural instructions is to portray objects in a manner so that necessary features are manifest.

(a) What are the salient functional features of some common objects?

(b) How do the presence or absence of such features in a graphic representation influence the ability to perceive functions of objects?

(c) Does the awareness of salient features differ when looking at a photograph versus looking at a fixed object or looking at an object that can be handled or manipulated?

(d) Is information from two dimensional pictures and three dimensional objects equivalent?

(e) Is functional information related to presentation orientation?

4. There are a series of questions concerned with individual differences that we wish to explore.

(a) How do experts differ from novices when acquiring meaning from picture-text combinations? How do good learners differ from poor when acquiring meaning from picture-text combinations?

(b) Are there large individual differences in the use of picture-text combinations?

(c) Can certain comprehension monitoring strategies that facilitate such performance be identified so that they may be taught to others?

(d) How do two important sources of individual differences, basic abilities and strategies or procedures influence the kind of performance? Are better learners distinguished from poorer learners on the basis of: 1) certain enduring ability traits such as spatial ability or 2) the use of certain trainable strategies such as comprehension monitoring skills, or 3) a combination of abilities and

strategies? Does the same pattern distinguish experts from novices?

Individual differences involving cognitive style dimensions have been explored relative to their compatibility with the mental operations necessary for effective processing of technical instructions for procedural tasks. (Crandell, 1979) Further studies using other quantifiable indices of structuring reading behaviors and of cognitive style models were recommended. We have elected to use the field dependent/field independent model of Witkin (1969) as a means of replicating or extending our earlier findings. To this end the following questions are posed:

- e) Are field-independents more cognitively compatible with the mental operations necessary for processing procedural instructions efficiently and accurately?
- f) Do field-independents complete a performance task more effectively when presented with instructions in a pictorial format?
- g) Are field-independents superior to field-dependents in their ability to process information of a technical nature regardless of the media format stimulus presented to the reader?
- h) Finally, does an interaction exist between FD/FI and media format design (picture on text) on a given set of instructions for completion of a performance task?

Further Questions Inviting Research Efforts

1. Do good and poor readers differ in their use of illustrations with text? If so how do they differ?
2. What changes occur in the beginning reader's use of text as

he or she becomes a skilled reader?

3. What changes occur in the reader's use of illustrations with text as the difficulty (i.e., vocabulary, sentence complexity, conceptual level, etc.) of text increases?

4. How may picture-text combinations be designed to facilitate the comprehension of different types of content (i.e., narrative, procedural, etc.)?

Additional questions of broader psychological import include:

1. How do readers extract the semantic features present in picture:text combinations?

2. How do readers select content of text and pictures for retention?

3. How do readers integrate the semantic content of pictures and text during the reading process?

4. What is the nature of the reader's mental representation of the meaning of text and picture?

5. How do readers integrate content of pictures and text with related prior knowledge?

6. How is such stored information subsequently retrieved?

7. How do the various tasks used to assess that information affect its use?

Research along these lines should not only provide greater insight into the nature of the reading process, but should have implications for the improved design of reading materials using picture-text combinations.

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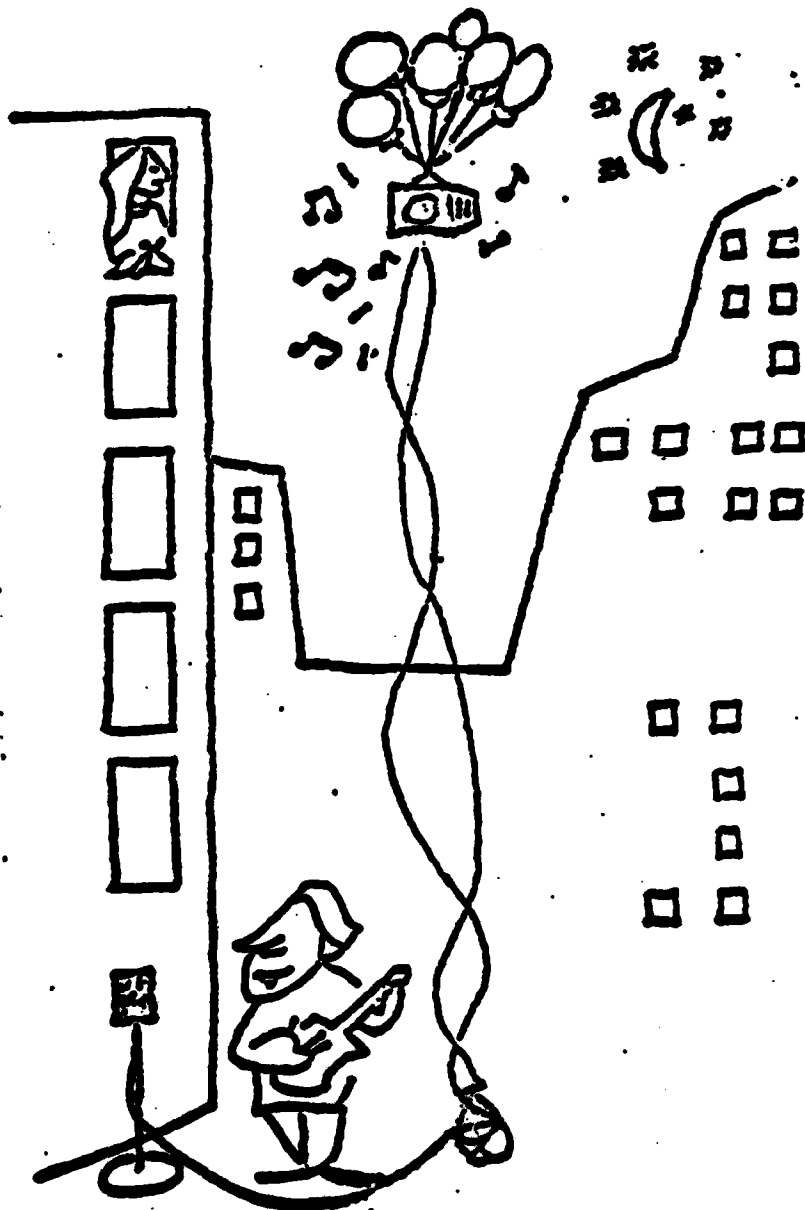
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Figure 1
Balloon Passage



From: Bransford and Johnson.

Figure 2

PROPOSITIONAL ANALYSIS: STONE ASSEMBLY INSTRUCTIONS

1. TO FORM COLUMN ONE: ASSEMBLE THREE LARGE BLOCKS END TO END. ATTACH A SMALL BLOCK TO THE TAB END OF COLUMN ONE.

```

1P01.01 ( )--AGT-->('FORM)
1P01.02 ('FORM)--OBJ-->(:COLUMN.1)
1P02.01 ( )--AGT-->('ASSEMBLE)
1P02.02 ('ASSEMBLE)--OBJ-->(:LARGE.BLOCK.1),(:LARGE.BLOCK.2),
(:LARGE.BLOCK.3)
1P02.03 (:LARGE.BLOCK.1),(:LARGE.BLOCK.2),(:LARGE.BLOCK.3)
<--ORIENT@p('END.TO.END)-->(:LARGE.BLOCK.1),(:LARGE.BLOCK.2),
(:LARGE.BLOCK.3)
1P02.04 ('ASSEMBLE)--GOAL-->"1P02.03
1P03.01 ( )--AGT-->('ATTACH)
1P03.02 ('ATTACH)--OBJ-->(:SMALL.BLOCK.1)
1P03.03 (:SMALL.BLOCK.1)--LOC@p('TAB.END)-->(:COLUMN.1)
1P04 "1P02,"1P03--GOAL-->"1P01

```

2. TO FORM COLUMN TWO: ASSEMBLE THREE OTHER LARGE BLOCKS END TO END. ATTACH THE OTHER SMALL BLOCK TO THE TAB END OF COLUMN TWO.

```

2P01.01 ( )--AGT-->('FORM)
2P01.02 ('FORM)--OBJ-->(:COLUMN.2)
2P02.01 ( )--AGT-->('ASSEMBLE)
2P02.02 ('ASSEMBLE)--OBJ-->(:LARGE.BLOCK.4),(:LARGE.BLOCK.5),
(:LARGE.BLOCK.6)
2P02.03 (:LARGE.BLOCK.4),(:LARGE.BLOCK.5),(:LARGE.BLOCK.6)
<--ORIENT@p('END.TO.END)-->(:LARGE.BLOCK.4),(:LARGE.BLOCK.5),
(:LARGE.BLOCK.6)
2P02.04 ('ASSEMBLE)--GOAL-->"2P02.03
2P03.01 ( )--AGT-->('ATTACH)
2P03.02 ('ATTACH)--OBJ-->(:SMALL.BLOCK.2)
2P03.03 (:SMALL.BLOCK.2)--LOC@p('TAB.END)-->(:COLUMN.2)
2P04 "2P02,"2P03--GOAL-->"2P01

```

3. TO FORM THE BACK: MOVE THE COLUMNS SO THAT THEY ARE PARALLEL WITH EACH OTHER. THEY SHOULD BE ABOUT THE WIDTH OF TWO BLOCKS APART. (BE SURE THAT THE TABS AT THE END OF EACH COLUMN POINT IN THE SAME DIRECTION.)

```

3P01.01 ( )--AGT-->('FORM)
3P01.02 ('FORM)--OBJ-->(:BACK)
3P02.01 ( )--AGT-->('MOVE)
3P02.02 ('MOVE)--OBJ-->(:COLUMN.1),(:COLUMN.2)
3P03 (:COLUMN.1)<--ORIENT@p('PARALLEL)-->(:COLUMN.2)
3P04 "3P02--GOAL-->"3P03
3P05.01 (:COLUMN.1)<--ORIENT@p('APART)-->(:COLUMN.2)
3P05.02 "3P05.01--DEG@('ABOUT)-->('TWO.BLOCK.WIDTHS)
3P06 (:COLUMN.1.TAB)<--ORIENT@p('IN.THE.SAME.DIRECTION)-->
(:COLUMN.2.TAB)
3P07.01 ( )--AGT-->('BE.SURE)

```

3P07.02 ('BE.SURE)--THEN-->"3P06

4. CONNECT THE TWO COLUMNS BY INSERTING FOUR FLAT PIECES BETWEEN THEM. SLIDE EACH FLAT PIECE INTO PLACE USING THE SIDE GROOVES IN THE BLOCKS. (ALL THE FLAT PIECES SHOULD HAVE THEIR SMOOTH SIDES ON THE SAME SIDE.) THEY MUST BE FLUSH WITH THE ENDS OF THE COLUMNS WITHOUT TABS.

```

4P01.01 ( )--AGT-->('CONNECT)
4P01.02 ('CONNECT)--OBJ-->(:COLUMN.1),(:COLUMN.2)
4P02.01 ( )--AGT-->('INSERT)
4P02.02 ('INSERT)--OBJ-->(:FLAT.PIECE.1),(:FLAT.PIECE.2),(:FLAT.PIECE.3),
(:FLAT.PIECE.4)
4P02.03 (:FLAT.PIECE.1),(:FLAT.PIECE.2),(:FLAT.PIECE.3),(:FLAT.PIECE.4)
--LOCp('BETWEEN)-->(:COLUMN.1),(:COLUMN.2)
4P03 "4P02--GOAL-->"4P01
4P04.01 ( )--AGT-->('SLIDE)
4P04.02 ('SLIDE)--OBJ-->(:FLAT.PIECE.1),(:FLAT.PIECE.2),(:FLAT.PIECE.3),
(:FLAT.PIECE.4)
4P05 "4P04--GOAL-->"4P02.03
4P06.01 ( )--AGT-->('USE)
4P06.02 ('USE)--OBJ-->(:SIDE.GROOVES)
4P07 "4P06--GOAL-->"4P05
4P08 (:SMOOTH.SIDE.1),(:SMOOTH.SIDE.2),(:SMOOTH.SIDE.3),
(:SMOOTH.SIDE.4),<--ORIENTp('SAME)-->(:SMOOTH.SIDE.1),
(:SMOOTH.SIDE.2),(:SMOOTH.SIDE.3),(:SMOOTH.SIDE.4)
4P09.01 (:FLAT.PIECE.1),(:FLAT.PIECE.2),(:FLAT.PIECE.3),(:FLAT.PIECE.4)
--LOCp('FLUSH.WITH)-->(:COLUMN.1.END.1),(:COLUMN.2.END.1)
4P09.02 (:COLUMN.1.END.1),(:COLUMN.2.END.1)--ATT-->('WITHOUT.TAB)
4P10 "5P02, ... "5P07,"4P01, ... "4P09--GOAL-->"5P01

```

5. TO FORM THE AXLE ASSEMBLY: ATTACH ONE ANGLE BLOCK TO THE END GROOVE OF COLUMN ONE AND ATTACH THE OTHER ANGLE BLOCK TO THE END GROOVE OF COLUMN TWO. (BE SURE THAT THE TABS OF THE ANGLE BLOCKS FACE THE SAME DIRECTION AS THE SMOOTH SIDES OF THE BACK.)

```

5P01.01 ( )--AGT-->('FORM)
5P01.02 ('FORM)--OBJ-->(:AXLE.ASSEMBLY)
5P02.01 ( )--AGT-->('ATTACH)
5P02.02 ('ATTACH)--OBJ-->(:ANGLE.BLOCK.1)
5P02.03 (:ANGLE.BLOCK.1)--LOCp('TO)-->(:COLUMN.1.END.GROOVE)
5P03.01 ( )--AGT-->('ATTACH)
5P03.02 ('ATTACH)--OBJ-->(:ANGLE.BLOCK.2)
5P03.03 (:ANGLE.BLOCK.2)--LOCp('TO)-->(:COLUMN.2.END.GROOVE)
5P04 (:ANGLE.BLOCK.1.TAB.1),(:ANGLE.BLOCK.2.TAB.1)<--ORIENTp
('SAME)-->(:BACK.SMOOTH.SIDE)
5P05.01 ( )--AGT-->('BE.SURE)
5P05.02 ('BE.SURE)--THEN-->"5P04

```

6. INSERT THE LONG ROD THROUGH THE TWO ANGLE BLOCKS.

```

4P01.01 ( )--AGT-->('INSERT)
4P01.02 ('INSERT)--OBJ-->(:LONG.ROD.1)
4P01.03 (:LONG.ROD.1)--LOCp('THROUGH)-->(:ANGLE.BLOCK.1),
(:ANGLE.BLOCK.2)

```


7. TO FORM THE BASE: FASTEN TWO LARGE BLOCKS END TO END TO FORM A SHORT COLUMN. ATTACH A THIRD LARGE BLOCK TO A FLAT PIECE BY INSERTING THE FLARED EDGE OF THE FLAT PIECE INTO A SIDE GROOVE OF THE BLOCK. (BE SURE THAT THE ENDS OF THE FLAT PIECE ARE FLUSH WITH THE ENDS OF THE BLOCK.)

```

7P01.01 ( )--AGT-->('FORM)
7P01.02 ('FORM)--OBJ-->(:BASE)
7P02.01 ( )--AGT-->('FASTEN)
7P02.02 ('FASTEN)--OBJ-->(:LARGE.BLOCK.7),(:LARGE.BLOCK.8)
7P02.03 (:LARGE.BLOCK.7)<--ORIENT@('END.TO.END)-->(:LARGE.BLOCK.8)
7P03.01 ( )--AGT-->('FORM)
7P03.02 ('FORM)--OBJ-->(:SHORT.COLUMN)
7P04 "7P02--GOAL-->7P03
7P05.01 ( )--AGT-->('ATTACH)
7P05.02 ('ATTACH)--OBJ-->(:LARGE.BLOCK.9),(:FLAT.PIECE.5)
7P06.01 ( )--AGT-->('INSERT)
7P06.02 ('INSERT)--OBJ-->(:FLAT.PIECE.5.FLARED.EDGE.1)
7P06.03 (:FLAT.PIECE.5.FLARED.EDGE.1)--LOC@('IN)-->
(:LARGE.BLOCK.9.SIDE.GROOVE)
7P07 "7P06--GOAL-->7P05
7P08 (:FLAT.PIECE.5.END.1),(:FLAT.PIECE.5.END.2)<--ORIENT@('FLUSH)-->
(:LARGE.BLOCK.9.END.1),(:LARGE.BLOCK.9.END.2)
7P09.01 ( )--AGT-->('BE.SURE)
7P09.02 ('BE.SURE)--THEN-->"7P08

```

8. ATTACH ANOTHER LARGE BLOCK TO THE OTHER FLARED EDGE OF THE FLAT PIECE IN THE SAME WAY. (BE SURE THAT THE TABS OF THE BLOCKS POINT IN THE SAME DIRECTION.)

```

8P01.01 ( )--AGT-->('ATTACH)
8P01.02 ('ATTACH)--OBJ-->(:LARGE.BLOCK.10),(:FLAT.PIECE.5.FLARED.EDGE.2)
8P02.01 ( )--AGT-->('INSERT)
8P02.02 ('INSERT)--OBJ-->(:FLAT.PIECE.5.FLARED.EDGE.2)
8P02.03 (:FLAT.PIECE.5.FLARED.EDGE.2)--LOC@('IN)-->
(:LARGE.BLOCK.10.SIDE.GROOVE)
8P03 "8P02--GOAL-->8P01
8P04.01 (:FLAT.PIECE.5.END.1),(:FLAT.PIECE.5.END.2)<--ORIENT@('FLUSH)-->
(:LARGE.BLOCK.10.END.1),(:LARGE.BLOCK.10.END.2)
8P05 (:LARGE.BLOCK.9.TAB)<--ORIENT@('SAME)-->(:LARGE.BLOCK.10.TAB)
8P06.01 ( )--AGT-->('BE.SURE)
8P06.02 ('BE.SURE)--THEN-->"8P05

```

9. INSERT THESE TWO TABS INTO A SIDE GROOVE OF THE SHORT COLUMN SO THAT THE SIDE OF THE SHORT COLUMN COVERS THE ENDS OF BOTH LARGE BLOCKS AND THE END OF THE FLAT PIECE.

```

9P01.01 ( )--AGT-->('INSERT)
9P01.02 ('INSERT)--OBJ-->(:LARGE.BLOCK.9.TAB),(:LARGE.BLOCK.10.TAB)
9P01.03 (:LARGE.BLOCK.9.TAB),(:LARGE.BLOCK.10.TAB)--LOC@('INTO)-->
(:SHORT.COLUMN.SIDE.GROOVE)
9P02 (:SHORT.COLUMN.SIDE.1)--LOC@('COVERS)-->(:LARGE.BLOCK.9.END),

```

9P03 (:ANGLE.BLOCK.10.END),(:FLAT.PIECE.5.END.1)
 "9P07--GOAL-->"9P03

10. TO ATTACH THE BASE TO THE AXLE ASSEMBLY: NOTICE THAT THE BASE HAS A COLUMN OF TWO LARGE BLOCKS. ONE SIDE OF THIS COLUMN HAS A FLAT PIECE ATTACHED TO IT. ATTACH THE OPPOSITE SIDE OF THIS COLUMN TO THE EXPOSED TABS OF THE AXLE ASSEMBLY. BE SURE THAT THE FLAT PIECE IN THE BASE HAS ITS SMOOTH SIDE UP.

```
10P01.01 ( )--AGT-->('ATTACH)
10P01.02 ('ATTACH)--OBJ-->(:BASE),(:AXLE.ASSEMBLY)
10P02 (:BASE)--HASP-->(:SHORT.COLUMN)
10P03.01 ( )--AGT-->('NOTICE)
10P03.02 ('NOTICE)--THEN-->"10P02
10P04 (:FLAT.PIECE.5)--LOC@p('ATTACHED.TO)-->(:SHORT.COLUMN.SIDE.1)
10P05 (:SHORT.COLUMN.SIDE.2)--LOC@p('OPPOSITE)-->
(:SHORT.COLUMN.SIDE.1)
10P06.01 ( )--AGT-->('ATTACH)
10P06.02 ('ATTACH)--OBJ-->(:SHORT.COLUMN.SIDE.2),(:ANGLE.BLOCK.1.TAB.2),
(:ANGLE.BLOCK.2.TAB.2)
10P07 (:FLAT.PIECE.5.SMOOTH.SIDE)--ATT-->('UP)
10P08.01 ( )--AGT-->('BE.SURE)
10P08.02 ('BE.SURE)--THEN-->"10P07
10P09 "10P02, ... "10P08--GOAL-->"10P01
```

11. TO FORM THE WHEEL ASSEMBLIES: PLACE A WASHER OVER EACH END OF A LONG ROD SO THAT THEY ARE FLUSH WITH THE ANGLE BLOCK.

```
11P01.01 ( )--AGT-->('FORM)
11P01.02 ('FORM)--OBJ-->(:WHEEL.ASSEMBLY.1),(:WHEEL.ASSEMBLY.2)
11P02.01 ( )--AGT-->('PLACE)
11P02.02 ('PLACE)--OBJ-->(:WASHER.1),(:WASHER.2)
11P02.03 (:WASHER.1),(:WASHER.2)--LOC@p('OVER)-->(:LONG.ROD.END.1),
(:LONG.ROD.END.2)
11P03 (:WASHER.1),(:WASHER.2)--LOC@p('FLUSH)-->(:ANGLE.BLOCK.1),
(:ANGLE.BLOCK.2)
11P04 "11P02--GOAL-->"11P03
```

12. PLACE A SCREW HUB OVER EACH END OF THE LONG ROD SO THAT THEIR THREADS POINT AWAY FROM THE ANGLE BLOCKS.

```
12P01.01 ( )--AGT-->('PLACE)
12P01.02 ('PLACE)--OBJ-->(:SCREW.HUB.1),(:SCREW.HUB.2)
12P01.03 (:SCREW.HUB.1),(:SCREW.HUB.2)--LOC@p('OVER)-->
(:LONG.ROD.END.1),(:LONG.ROD.END.2)
12P02 (:SCREW.HUB.1.THREADS)--ORIENT@p('AWAY)-->(:ANGLE.BLOCK.1)
12P03 (:SCREW.HUB.2.THREADS)--ORIENT@p('AWAY)-->(:ANGLE.BLOCK.2)
12P04 "12P01--GOAL-->"12P02,"12P03
```

13. NEXT PLACE A TIRE OVER EACH END OF THE ROD. NEXT PLACE A NUT HUB OVER EACH END OF THE LONG ROD WITH THEIR WINGS AWAY FROM THE SCREW HUB. SCREW THE NUT HUBS AND SCREW HUBS TOGETHER WITH THE TIRES BETWEEN

THEN.

FINALLY, PLACE A WASHER OVER EACH END OF THE LONG ROD SO THAT THEY ARE FLUSH WITH THE SCREW HUBS.

```

13P01.01 ( )--AGT-->('PLACE)
13P01.02 ('PLACE)--OBJ-->(:TIRE.1),(:TIRE.2)
13P01.03 (:TIRE.1),(:TIRE.2)--LOC@p('OVER)-->(:LONG.ROD.END.1),
(:LONG.ROD.END.2)
13P02.01 ( )--AGT-->('PLACE)
13P02.02 ('PLACE)--OBJ-->(:SCREW.HUB.1),(:SCREW.HUB.2)
13P02.03 (:SCREW.HUB.1),(:SCREW.HUB.2)--LOC@p('OVER)-->(:LONG.ROD.END.1),
(:LONG.ROD.END.2)
13P02.04 (:SCREW.HUB.1.WINGS)<--ORIENT@p('AWAY FROM)-->(:NUT.HUB.1)
13P02.05 (:SCREW.HUB.2.WINGS)<--ORIENT@p('AWAY FROM)-->(:NUT.HUB.2)
13P03.01 ( )--AGT-->('SCREW)
13P03.02 ('SCREW)--OBJ-->(:NUT.HUB.1),(:SCREW.HUB.1)
13P03.03 ('SCREW)--MATT-->('TOGETHER)
13P03.04 (:TIRE.1)--LOC@p('BETWEEN)-->(:NUT.HUB.1),(:SCREW.HUB.1)
13P04.01 ( )--AGT-->('SCREW)
13P04.02 ('SCREW)--OBJ-->(:NUT.HUB.2),(:SCREW.HUB.2)
13P04.03 ('SCREW)--MATT-->('TOGETHER)
13P04.04 (:TIRE.2)--LOC@p('BETWEEN)-->(:NUT.HUB.2),(:SCREW.HUB.2)
13P05.01 ( )--AGT-->('PLACE)
13P05.02 ('PLACE)--OBJ-->(:WASHER.3),(:WASHER.4)
13P05.03 (:WASHER.3),(:WASHER.4)--LOC@p('OVER)-->(:LONG.ROD.END.1),
(:LONG.ROD.END.2)
13P06.01 (:WASHER.3)--LOC@p('FLUSH)-->(:SCREW.HUB.1)
13P06.02 (:WASHER.4)--LOC@p('FLUSH)-->(:SCREW.HUB.2)
13P07 "13P05--GOAL-->"13P06
13P08 "12P02, ... "13P07--GOAL-->"11P01

```

14. TO FORM HANDLE ONE: INSERT A SHORT ROD THROUGH A CLIP SO THAT THE CLIP IS IN THE MIDDLE OF THE ROD.

```

14P01.01 ( )--AGT-->('FORM)
14P01.02 ('FORM)--OBJ-->(:HANDLE.1)
14P02.01 ( )--AGT-->('INSERT)
14P02.02 ('INSERT)--OBJ-->(:SHORT.ROD.1)
14P02.03 (:SHORT.ROD.1)--LOC@p('THROUGH)-->(:CLIP.1)
14P03 (:CLIP.1)--LOC@p('IN.THE.MIDDLE.OF)-->(:SHORT.ROD.1)
14P04 "14P02--GOAL-->"14P03
14P05 "14P04--GOAL-->"14P01

```

15. TO FORM HANDLE TWO: INSERT ANOTHER SHORT ROD THROUGH ANOTHER CLIP SO THAT THE CLIP IS IN THE MIDDLE OF THE ROD.

```

15P01.01 ( )--AGT-->('FORM)
15P01.02 ('FORM)--OBJ-->(:HANDLE.2)
15P02.01 ( )--AGT-->('INSERT)
15P02.02 ('INSERT)--OBJ-->(:SHORT.ROD.2)
15P02.03 (:SHORT.ROD.2)--LOC@p('THROUGH)-->(:CLIP.2)
15P03 (:CLIP.2)--LOC@p('IN.THE.MIDDLE.OF)-->(:SHORT.ROD.2)
15P04 "15P02--GOAL-->"15P03
15P05 "15P04--GOAL-->"15P01

```

16. NEXT, THE HANDLES SHOULD BE INSERTED IN THE END OF THE BACK WITH EXPOSED TABS. EACH HANDLE SHOULD BE INSERTED IN THE GROOVES AT THE FRONT OF THE BACK SO THAT THE CLIPS ARE RESTING AGAINST THE ENDS OF THE BLOCKS. THE OPENINGS ON ONE SIDE OF EACH CLIP SHOULD FIT OVER THE TABS AT THE ENDS OF THE COLUMNS. THIS COMPLETES THE ASSEMBLY OF THE LOADING CART.

```

16P01.01 ( )--AGT-->('INSERT)
16P01.02 ('INSERT)--OBJ-->(:HANDLE.1),(:HANDLE.2)
16P01.03 (:HANDLE.1),(:HANDLE.2)--LOC@p('IN)-->(:COLUMN.1.END.2),
(:COLUMN.2.END.2)
16P02.01 (HANDLE.1),(:HANDLE.2)--LOC@p('IN)-->(:COLUMN.1.FRONT.GROOVE),
(:COLUMN.2.FRONT.GROOVE)
16P03 (:CLIP.1),(:CLIP.2)--LOC@p('AGAINST)-->(:COLUMN.1.END.2),
(:COLUMN.2.END.2)
16P04 "16P02--GOAL-->"16P03
16P05.01 (:CLIP.1.OPENING)--LOC@p('OVER)-->(:COLUMN.1.TAB)
16P05.02 (:CLIP.2.OPENING)--LOC@p('OVER)-->(:COLUMN.2.TAB)

```

Figure 3
Plates of Illustrations
(not shown in accurate scale)

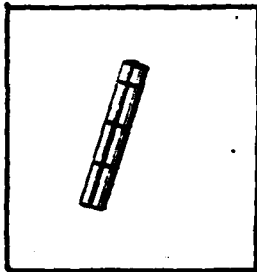


Plate #1

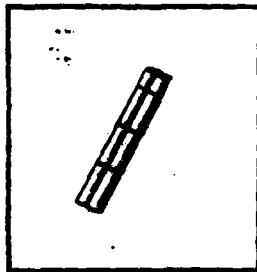


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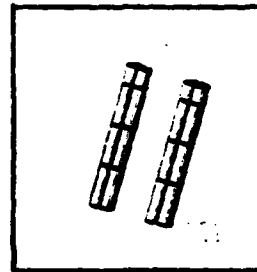


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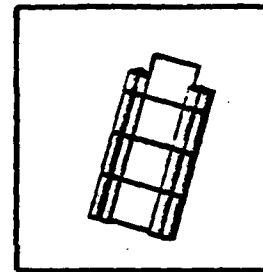


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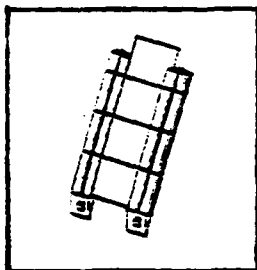


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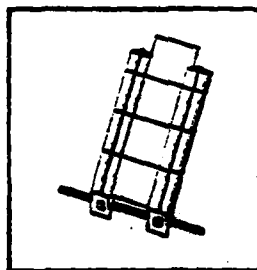


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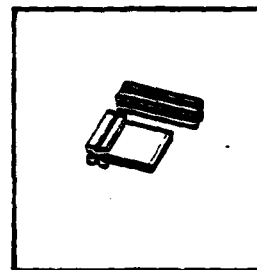


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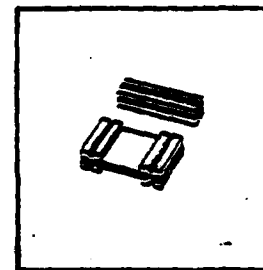


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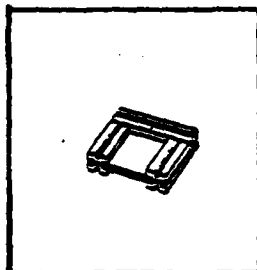


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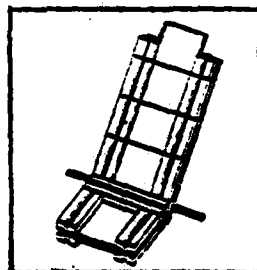


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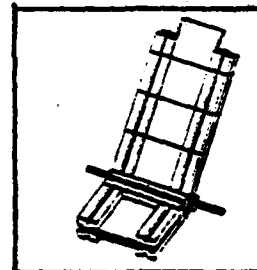


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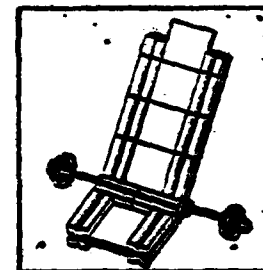


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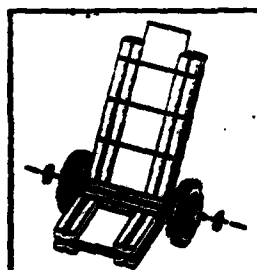


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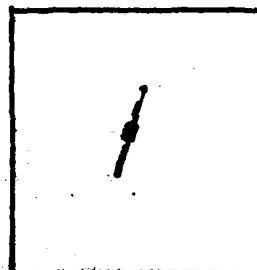


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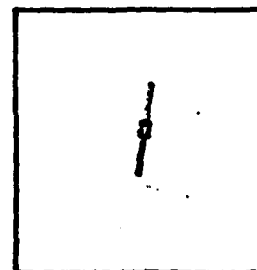


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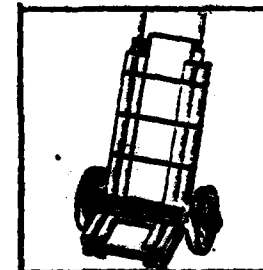


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