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Contextual Memory Effects in Problem Solving

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CONTEXTUAL MEMORY EFFECTS IN PROBLEM SOLVING

by

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VITA

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CHAPTER I

INTRODUCTION

A central problem in the study of sentence memory is the common observation that we are better able to remember the "gist" of sentential material than we are the exact verbal structure of that material (e.g., Fillenbaum, 1966; Gomulicki, 1956; Jarvella, 1971; Sachs, 1967). Interest in this issue has advanced through several areas of investigation: a) several theorists have suggested that the effect is due to the interpretation of the deep structural relations of sentences; b) numerous other researchers have argued that sentence memory is constructive, rather than interpretative, in nature; c) the role of one's present cognitive knowledge in this process of sentence memory has been examined; and d) the importance of the availability of contextual information in the use of previously acquired knowledge has been discussed.

The present paper begins by sketching the development of sentence memory through each of these areas of investigation. The general approach to comprehension and memory deriving from this discussion is then applied to the study of problem-solving processes. In the experiments that are reported in the present study, subjects were given a paragraph of English text to read. Each subject was then presented a problem concerning the material contained in the paragraph, and was asked to solve the problem using supplementary information which was

provided. Data from these experiments were used to test several predictions concerning the effects of various context conditions upon the comprehension and storage of sentences, and the subsequent use of this information in the solution of an algebra word problem.

Sentence Memory

Interpretative Approach. Several attempts to account for sentence memory have relied heavily upon concepts developed within transformational linguistic theory (Chomsky, 1957, 1965, 1968). Prominent among these attempts has been the interpretative approach of Postal (Postal, 1964; Katz & Postal, 1964). This approach is based upon the contention that a sentence consists of both a surface structure and a deep structure. The surface structure characterizes the phonological shape of the sentence, while the interpretation of the deep structure comprises the cognitive meaning of the sentence. It is assumed that this semantic interpretation of the deep structural relations of the sentence is necessary for comprehension, and that this interpretation completely characterizes the information that is stored. There have been a large number of studies which seem to support such an interpretative approach to sentence retention (e.g., Bever, Lackner, & Kirk, 1969; Blumenthal, 1967; Blumenthal & Boakes, 1967; Gough, 1965; Mehler, 1963; Miller, 1962; Perfetti, 1969; Savin & Perchonock, 1965). However, several other researchers (e.g., Barclay, 1973; Bransford, Barclay, & Franks, 1972; Bransford & Franks, 1971) have presented data and arguments in support of a constructive approach to sentence memory.

Constructive Approach. Proponents of a constructive view of sentence memory contend that the semantic interpretation of the deep struc-

ture of a sentence fails to provide a sufficient characterization of what is stored. They argue that while the interpretation of the deep structure of a sentence is likely necessary for the comprehension of that sentence to take place, the sentence's cognitive meaning is a function of the complete semantic descriptions that are constructed, and not the particular information specified by the linguistic inputs. They view sentences as sources of information that can be used to construct semantic descriptions of situations; descriptions which frequently contain more information than is represented in the linguistic objects. It is these semantic descriptions that are stored by an individual in the process of sentence memory, not the deep structural information underlying the sentence.

Interpretative vs. Constructive. A detailed consideration of the study conducted by Bransford et al. (1972) may serve to clarify the interpretative vs. constructive controversy in investigations of sentence memory. In this study, stimulus materials similar to the following two sentences were employed:

(1). "Three turtles rested beside a floating log, and a fish swam beneath them."

(2). "Three turtles rested on a floating log, and a fish swam beneath them."

These two sentences, which differ only in the use of the word "beside" or "on", describe situations which have vastly different semantic implications. Whereas both sentence (1) and sentence (2) state that the fish swam beneath the turtles, sentence (2) implies the additional information that the fish swam beneath the log. This latter information is not

explicitly provided by the linguistic objects contained in sentence (2), and is therefore not accessible simply through an interpretation of the deep structural relations of that sentence. This information is accessible, however, if a person uses his general knowledge of the world, and actively constructs a semantic description of the situation which goes beyond the information represented by the linguistic objects in sentence (2).

Bransford et al. (1972) used sentences similar to sentence (1) and sentence (2), presenting them to the subjects with the instructions that questions about these sentences would be asked later. Following the presentation of these acquisition sentences, the subjects were presented a second set of sentences, some of which they had heard previously in the acquisition list and some of which they had not, and they were instructed to state which of these test sentences were identical to those presented earlier. It was found that when subjects were presented a new test sentence in which only the final pronoun differentiated that sentence from, for example, acquisition sentence (1) (e.g., "Three turtles rested beside a floating log and a fish swam beneath it"), they had no difficulty recognizing that new sentence as different from sentence (1). However, when subjects were presented the new test sentence, "Three turtles rested on a floating log and a fish swam beneath it", they were unable to discriminate this new sentence from sentence (2). In the former example, subjects were able to recognize the new sentence as new since it described a situation different from that conveyed by sentence (1) (i.e., the fish swam beneath the turtles vs. the fish swam beneath the log, respectively). However,

in the latter condition, the new test sentence and sentence (2) provided information that could be used to construct semantically similar situations (e.g., the fish swam beneath the log), which resulted in recognition errors.

These basic findings have been replicated and corroborated under varied experimental conditions (Barclay, 1973; Barclay & Reid, 1974; Bransford & Franks, 1971, 1972; Cofer, 1973; Flagg, Potts, & Reynolds, 1975; Franks & Bransford, 1971, 1972; Johnson, Bransford, & Solomon, 1973; Katz, 1973; Katz, Atkeson, & Lee, 1974; Potts, 1972; Singer, 1973; Singer & Rosenberg, 1973). In these studies it was consistently demonstrated that subjects did not store representations of the deep structural information of the individual acquisition sentences; rather, they actively processed the sentential information, constructing semantic representations which embodied inferred as well as explicitly expressed information. These results suggest that linguistic inputs are not simply perceptual objects that may later be recalled or recognized; they are a source of information which a person interprets and stores within the context of his present cognitive knowledge. When an individual hears a sentence (or a paragraph), he processes that information in view of what he knows about the world. It is this synthesis of previous knowledge and present input which determines the semantic description of that information, and it is this description which characterizes what is stored by the individual. As Bransford, Barclay, & Franks (1972) stated, words do not carry meaning; "people carry meanings, and linguistic inputs merely act as cues which people can use to recreate and modify their previous knowledge of the world"

(p. 207).

Present Cognitive Knowledge. This contention that semantic representations are the result of the constructive interplay of sentential information and one's existing cognitive structures has been supported by Kintsch and Monk (1972). In this study, subjects were presented one of two versions of a paragraph, either a simple version or a complex version. In the simple version of the paragraph, very basic syntax was used to generate several simple sentences which clearly and logically expressed the underlying propositions of the paragraph. In the complex version, on the other hand, while the underlying propositions of the simple paragraph remained intact, they were in this condition expressed in one, long, complex sentence which was generated through the use of several grammatical and syntactic transformations. The following paragraphs illustrate examples of a simple and a complex version of the same paragraph.

Simple: "The council of elders in the land of Syndra meets whenever a stranger arrives. If the council meets and if the stranger presents the proper gifts to the council, he is not molested by the natives. The explorer Portmanteau came to Syndra without any valuable gifts."

Complex: "The arrival of strangers in the land of Syndra, like the explorer Portmanteau, who did not bring valuable gifts, always resulted in the meeting of the council of elders, which insured that the stranger was not molested by the natives upon receipt of the proper gifts."

Half the subjects in each of the simple- and complex-paragraph condi-

tions were allowed an indefinite amount of reading time, while the remaining subjects were given only a limited amount of time in which to read the paragraph. Once a paragraph had been read by a subject, he was asked to answer an inferential question concerning the information contained in that paragraph (e.g., "Was Portmanteau molested by the natives?").

Kintsch and Monk found that if subjects were restricted in the amount of reading time allowed, then those subjects in the simple-paragraph conditions were able to answer the inferential questions more accurately than were those subjects in the complex-paragraph conditions. If subjects were given an unlimited amount of reading time, however, then the accuracy with which the questions were answered was found to be unrelated to the original wording of the paragraph. These and similar results (see Greeno, 1974; King & Greeno, 1974) indicate that grammatical and syntactic variables <u>can</u> affect the ease with which the information contained in a paragraph may be assimilated by an individual. However, as long as sufficient time to process and store the information in a paragraph is allowed, then an individual is able to construct a representation of that information which is independent of these format variables (i.e., he is able to assimilate that information into his present cognitive knowledge). As a result, his ability to answer inferential questions is unaffected by the grammatical and syntactic complexity of the paragraph. Thus, to the extent that an individual is able to assimilate sentential information into his existing cognitive structures, he will be better able to use that information in subsequent tasks.

Availability of Contextual Information. The importance of contextual information in the assimilation of linguistic inputs into one's previously acquired knowledge structures has been discussed by several theorists and researchers (e.g., Blumenthal, 1970; Dooling, 1972; Harris, 1974; Haviland & Clark, 1974; Norman, 1973; Olson, 1970). Blumenthal, for example, has suggested that contextual information acts as a prerequisite for the comprehension and retention of prose materials; that is, an individual is capable of relating sentential information to his existing cognitive knowledge only to the extent that appropriate contextual information is available. Regardless of how well a sentence is organized and expressed, the information conveyed by that sentence will not be comprehended and remembered unless the same contextual "field" is shared to some extent by both the speaker and the listener.

There have been several studies in which the facilitating effects of contextual information upon sentence memory have been demonstrated. Doll and Lapinsky (1974) and Johnson, Doll, Bransford, and Lapinsky (1974) found that when subjects were instructed to learn a series of unrelated sentences, each of which was constructed such that its contextual referent was not clearly specified (e.g., "He kicked twice but got no change."), those subjects who were provided appropriate contexts (e.g., "vending machine") were better able to recall the list of sentences than were those subjects who did not receive contextual cues. Similar results have been obtained in studies in which the availability of contextual information has been manipulated through the presentation of prose passages in their proper syntactic order vs.

either a random word order (Lachman & Dooling, 1968; Philipchalk, 1972; Pompi & Lachman, 1967; Yuille & Paivio, 1969) or a random sentence order (Meyers & Boldrick, 1975). It has been consistently demonstrated in these studies that those subjects who received the intact presentation of a prose passage, which served to maintain and to convey the context of the passage, were subsequently more likely to recall or to recognize theme-related words than were those subjects who were presented random arrangements of the prose passage.

Dooling and Lachman (1971) have also investigated the effects of contextual information upon memory for prose passages. In this study, short paragraphs based upon clear and coherent themes were constructed such that each of these themes was difficult to grasp without some thematic cue. For example, Dooling and Lachman used the following paragraph in their study:

> "WITH HOCKED GEMS FINANCING HIM / OUR HERO BRAVELY DEFIED ALL SCORNFUL LAUGHTER / THAT TRIED TO PREVENT HIS SCHEME / YOUR EYES DECEIVE / HE HAD SAID / AN EGG / NOT A TABLE / CORRECTLY TYPIFIES THIS UNEXPLORED PLANET / NOW THREE STURDY SISTERS SOUGHT PROOF / FORGING ALONG SOMETIMES THROUGH CALM VASTNESS / YET MORE OFTEN OVER TURBULENT PEAKS AND VALLEYS / DAYS BECAME WEEKS / AS MANY DOUBTERS SPREAD FEARFUL RUMORS ABOUT THE EDGE / AT LAST / FROM NOWHERE / WELCOME WINGED CREATURES APPEARED / SIGNIFYING MOMENTOUS SUCCESS"

Half of the subjects who were presented this passage were also presented the following thematic title: "Christopher Columbus Discovering America"; the remaining subjects were not given a title for the passage. Despite

the fact that all the subjects were familiar with the lexical meanings of the words and the syntactic structures used in the passage, it was found that recall of the paragraph was much better for those subjects who were given the appropriate context before reading a passage than it was for those subjects who did not receive thematic titles.

While these results clearly indicate the facilitating effects of contextual information upon the recall of prose passages, they fail to specify the locus of this effect: did the thematic titles produce more efficient storage of the materials at input? or, did they aid in the reconstruction of the materials during recall? In an effort to evaluate the relative strengths of these alternatives, Bransford and Johnson (1972, 1973) and Dooling and Mullet (1973) used prose passages similar to those employed by Dooling and Lachman (1971), and they presented subjects with an appropriate thematic title a) before a passage was read, b) after a passage was read, or c) not at all. It was found that those subjects in the Topic Before condition scored much higher, both in terms of comprehension and recall, than did those subjects in the Topic After condition. Furthermore, the Topic After subjects performed little better than did the Control subjects who were never presented a thematic title. Since the Topic Before subjects had the benefit of the title both during storage and during recall, whereas the Topic After subjects were only able to use this contextual cue during recall, these results support the suggestion that the availability of the appropriate context serves as an aid in the <u>storage</u> of stimulus materials.

An explanation of how this contextual facilitation during storage is accomplished has been offered by Bransford and Johnson (1972, 1973).

As we have seen, simply having relevant preexperimental knowledge does not guarantee its usefulness for sentence comprehension and memory. Potentially meaningful material may be rendered incomprehensible if the appropriate prior knowledge of the situation is not activated by some contextual cue while the materials are being processed. Bransford and Johnson therefore contend that contexts enable an individual to interpret and organize input materials in a manner which is consistent with his prior knowledge of the world. They suggest that the extent to which a prose passage may be remembered is largely a function of how well an individual is able to use his prior knowledge to interpret and store the incoming information. They have received support for this suggestion from postexperimental interviews with those subjects in Bransford and Johnson (1972, 1973) who were presented prose passages without their accompanying thematic titles. These subjects reported that if sufficient cues as to a passage's semantic context were not available, then they actively searched for some way to make sense of the passage; in other words, they attempted to find or formulate a suitable organization of personal existing cognitive structures into which the incoming information might be integrated. While most of these subjects were able to "make sense of", and therefore to remember, some portion of each passage, rarely did an individual manage to locate a context which enabled him to remember an entire passage.

Context can thus be seen to play an important role in the processing of information, such that the accuracy with which linguistic inputs are comprehended and remembered is largely a function of the extent to which they may be integrated into one's cognitive structure,

which, in turn, is highly dependent upon the availability of appropriate contextual information. So strong is this influence of context, in fact, that Huttenlocher and Weiner (1971) and Trabasso (1973) have stated that data from experiments in which contextual factors are ignored have, at best, limited applicability.

Problem Solving

Memory in Problem Solving.

The methodological and theoretical perspective provided by the research discussed thusfar offers a framework within which the investigation of problem-solving processes may be interpreted. In their discussions of problem-solving behavior, numerous researchers and theorists (e.g., Duncan, 1959; Gagné, 1964; Greeno, 1973; Hayes, 1965; Neisser, 1967; Posner, 1973) have emphasized the importance of memory in problem solving. When an individual comes to the problem situation, he brings with him information, capabilities, and strategies which he has learned and remembers from previous experience and training. In the process of solving the problem, the individual must use those learned conceptions, selectively retrieving from his memory those ideas and methods which are relevant to the problem.

Gagné (1964) has suggested that the mere presence of this relevant information in memory is sufficient for problem solution. It has been frequently noted (e.g., Bourne, Ekstrand, & Dominowski, 1971; Cofer, 1957; Maier, 1970; Maltzman, 1955; Simon & Lea, 1974), however, that despite the fact that most problems consist of situations in which the essential information and mental capacity necessary for problem solution are readily available to the individual, many problems remain unsolved for extended (and often indefinite) periods of time. In Duncker's (1945)

candle problem, for example, the subjects are required to attach a candle to the wall in such a way that it will burn without dripping wax on the floor. In spite of the fact that the subjects are provided with the necessary materials (i.e., a candle, a small box, some tacks, and some matches) and have the necessary knowledge to obtain the solution (which consists of attaching the box to the wall with the tacks and then placing the lighted candle on the box), the problem is frequently solved only after a hint as to its solution has been given. While several researchers (e.g., Bartlett, 1958; Bruner, 1957; Koffka, 1957; Raaheim, 1971) have suggested that the realization of such problem solutions is retarded by the existence of a situational "gap" which prevents the transformation of the problem state into the desired goal state, explanations of this "gap" have generally been as vague and elusive as the term itself (see Berlyne, 1965; Davis, 1966; Neimark & Santa, 1975).

Context and Knowledge Orgainzation in Problem Solving. It is this author's contention that the presence of this "gap" in the problem situation derives from the learned information brought to the problem by the individual. Utilization of such information is dependent not only upon its existence in memory, but also upon its relation to the circumstances and conditions of the situation at hand. If the presentation of a problem situation fails to activate relevant existing cognitive structures within an individual, then the information contained in those structures will be unavailable for use in obtaining the solution to the problem. To the extent that an individual is provided contexts that will enable him to interpret and organize problem materials in a

manner which is consistent with his prior knowledge of the world, he will exhibit successful problem-solving behavior.

Support for this contention has been obtained by Katona (1940). In his investigations of learning and problem solving, Katona found that learning through understanding aided subsequent problem-solving performance much more than did either learning by rule or learning by rote. It was suggested that these basic findings, which have been corroborated by several researchers (e.g., Forgus & Schwartz, 1957; Gagné & Brown, 1961; Haslerud & Meyers, 1958; Hilgard, Edgren, & Irvine, 1954; Hilgard, Irvine, & Whipple, 1953), resulted from the development of differential information structures by the subjects within the different learning conditions. While the understanding condition resulted in the learning of "meaningful organization", the principle-learning and memorization conditions produced learning of "senseless connections". In an attempt to account for this learning of "meaningful organization" through understanding, Gagné and Brown (1961) suggested that learning with understanding requires an individual to "reinstate", or actively produce, concepts which can later be used to solve new problems. This reinstatement of concepts, which Gagné and Brown pointed out may arouse previously acquired cognitive organizations within the individual [for further support of this suggestion, see Ausubel (1968) and Piaget (1970)], better enables the use of acquired knowledge in novel situations than does rote learning.

Consistent with this position, Greeno (1972) and his associates (Egan & Greeno, 1973; Mayer & Greeno, 1972) found that when subjects were taught to use the binomial distribution through the use of a

formula (i.e., rule learning), performance was better on subsequent test problems which could be solved by a straightforward use of the formula than it was on problems that required an interpretation of the formula. Those subjects, however, who were taught to use the binomial distribution through instructions which explained the variables in the formula in terms of concepts which were part of the subject's general understanding of random events (i.e., learning by understanding), excelled both on those test problems which required a straightforward use of the formula and on those problems requiring an interpretational use of the formula. These findings indicate, as was suggested by Katona (1940), that learning by understanding and learning by rule produce differences not only in the quantity of learning, but also in the quality of that learning. As Greeno and his co-workers pointed out, learning to use the binomial distribution through an "understanding" of its relevant variables enabled subjects to realize relationships between the new material and their present knowledge. This realization led to the establishment of new links among existing knowledge structures and made possible the integration of the new information into these cognitive organizations. Learning by rule, however, deemphasized the connections between the new material and the subjects' previous knowledge of the world, and prompted subjects to add new components to their existing cognitive structures. These new components may have been well organized among themselves (a situation which Mayer and Greeno termed "internal connectedness"), but such an organization was useful only in the solution of problems which required a simple computational use of these components. It was only when the new information was

connected to other elements in an individual's general cognitive organization (i.e., "external connectedness") that the person performed well both on those problems requiring a direct application and on those requiring an interpretation of the new information.

Greeno (1973) has similarly suggested that there are two ways in which an individual's knowledge might be organized. The first of these, which is comparable to the "internal connectedness" discussed above, has been labeled "algorithmic knowledge" by Greeno. This type of knowledge organization, which simply consists of an ability to use a relevant set of rules, does not involve an understanding of the operation of those rules. The second type of knowledge organization, which has been termed "propositional knowledge" (see Kintsch, 1972), corresponds to the "external connectedness" discussed by Mayer and Greeno. In Propositional knowledge, the information presented is contextually linked to the general ideas already in the subject's semantic memory; that is, the new information is "embedded" in the person's general knowledge of the world.

In an effort to manipulate the development of these two types of knowledge organization within subjects, Greeno (1973), Kieras and Greeno (1975), and Mayer and Greeno (1975) conducted experiments in which subjects were required to memorize either a set of conceptually meaningful formulas or a set of equivalent formulas which were stated in terms of semantically nonmeaningful letters. For example, the following equations were used to describe an hypothetical automobile trip:

Driving time = arrival time - leaving time

Distance = driving time x average speed

Gas mileage = distance / gas used

Total time = driving time + preparation time.

The following equivalent equations using nonmeaningful letters were alternatively employed:

$V = F - L$

$D = V \times A$

$M = D / G$

$T = V + P.$

In the case of the former equations, the information presented has cognitive meaning for the subject; that is, it can be understood in relation to the subject's knowledge of traveling time, speed, distance, gas consumption, etc. In the case of the nonmeaningful equations, however, while strong rigid connections among the variables in the formulas are fostered, there are no contextual cues which might enable an individual to relate the information provided to his existing cognitive knowledge. As a result, one might expect subjects to better comprehend and remember the information provided when the meaningful equations are presented than when the nonmeaningful formulas are used, which should result in superior problem-solving performance in the former situation. Consistent with this expectation, Mayer and Greeno (1975) found that subjects who received the meaningful equations performed much better on subsequent problem-solving tasks than did those subjects who were presented the nonmeaningful equations.

Incomplete Information in Problem Solving. Duncker (1945) has pointed out that in solving a problem, an individual must consider the

behavioral constraints that are imposed upon the problem solution by the restricting requirements surrounding the problem situation. As this statement suggests, an important element in efficient problem-solving behavior is the ability to recognize conditions which fail to satisfy the restrictions which encompass the problem situation (Mayer & Greeno, 1972). Support for this contention has been obtained by Paige and Simon (1966). These researchers found that when subjects were required to solve an algebra word problem, those subjects who reported having constructed a conceptual image of the problem elements, thus relating these elements to their knowledge of the world, were better able to detect inconsistencies in the task requirements than were those subjects who reported that they had attempted to solve the problem by means of more mechanical, or algorithmic, manipulations of the problem elements. Greeno (1973) similarly reported that those subjects who were presented a problem situation which consisted of semantically meaningful equations, which resulted in a propositional knowledge of the problem elements, were able to detect incomplete and inconsistent information in the structure of the problem more easily than were those subjects who were presented equivalent nonmeaningful equations describing the problem situation. These results indicate that to the extent that an individual is able to restructure and integrate the elements of a problem situation into his existing cognitive structure, the better will he be able to detect inconsistencies and incomplete information in that problem situation.

Transformational Use of Information in Problem Solving. Egan and Greeno (1973) and Mayer and Greeno (1975) have similarly suggested that

whether or not an individual is able to relate the elements of the problem situation to his knowledge of the world has a strong effect upon his ability to handle modifications of the presentation format of those elements. As Mayer and Greeno observed, those subjects who were presented a problem situation consisting of nonmeaningful equations retained the presentation organization of the problem elements much more rigidly than did those subjects who received the meaningful equations. These findings indicate that the more an individual is able to organize and integrate the elements of a problem situation into his existing knowledge structure, the more flexible will be his use of those elements; that is, the better will he be able to transform, or reinterpret, those elements.

The Present Study

Two experiments were conducted in the present study. In each of these experiments subjects were presented a problem situation, a statement of the problem to be solved, and a set of items of information which were to be used in the solution of that problem. The problem used was logically structured, and the information provided enabled a solution to be obtained in a logical and straightforward manner; that is, the solution could be obtained through the selection of a specific sequence of the informational items. Such an organized sequence of responses made in an effort to achieve the solution to a problem has been termed a "strategy" (Bourne et al., 1971). To the extent that a subject's strategy approximates the logical structure of the problem, his strategy may be said to be efficient. In the present study, a measure of problem-solving efficiency was

obtained through an analysis of the number of items of information required by each subject to solve the problem. In addition to this Efficiency Score, measures were also taken on the total time to solution, the time required for the preparation of a solution strategy, the inter-item latencies, and the accuracy of the problem solution given by the subject.

Experiment I. The first experiment conformed to a factorial crossing of three treatment variables, with two levels per variable. Half the subjects in this experiment recieved a statement of the problem situation in which a thematic cue was presented which provided an appropriate context for the problem. The remaining subjects were presented the same statement of the problem situation, except that no contextual information was provided. Each subject was then presented a set of items of information which was to be used in the solution of the problem. This set of items of information was structured in such a way that half the subjects in each of the context and no-context conditions was permitted to select either of two possible solution strategies in order to solve the problem. The specific strategy used by an individual was indicated by the informational items which he selected in the process of solving the problem. The remaining subjects in each of the context and no-context conditions were presented a restricted set of informational items. This set of items of information was structured such that these latter subjects were restricted to the use of only one of the two solution strategies. Each of these latter subjects was presented additional items of information which provided some

of the information required for the use of the solution strategy which was not permitted; however, these additional items failed to provide all of the information necessary for the use of this alternate strategy. Thus these latter subjects in Experiment I were provided "incomplete" information.

The wording of the items of information presented to the subjects was also manipulated in Experiment I. For half the subjects in each of the four categories generated by the factorial crossing of the availability of a contextual cue and the number of allowed solution strategies, the items of information provided were stated in terms of positive sentences; the remainder of the subjects received equivalent negative statements. It has been consistently demonstrated (e.g., Clark & Chase, 1972; Slobin, 1966; Trabasso, Rollins, & Shaughnessy, 1971; Wason, 1961) that due to the transformations, or reinterpretations, necessary for the comprehension of negative sentences, positive statements require less time for comprehension than do equivalent negative sentences.

Experiment II. The second experiment consisted of a 2 x 3 x 2 factorial design in which the three treatment variables were completely crossed. Two versions of the statement of the problem situation were employed in this experiment. Half of the subjects were presented a simple version of the problem situation in which several simple sentences were used which clearly explained the problem situation. The remaining subjects were presented a complex version of the problem situation in which one long, complex sentence was used to explain the problem situation.

The availability of a thematic cue was manipulated in Experiment II such that an equal number of subjects in each of the simple- and complex-paragraph conditions was provided an appropriate context a) before reading the statement of the situation, b) after reading the statement of the problem situation, but before attempting to solve the problem, or c) not at all.

The amount of reading time allowed each subject was also manipulated in Experiment II. For half the subjects in each of the six conditions resulting from the factorial crossing of paragraph complexity and availability of the contextual cue, a single reading of the statement of the problem situation was allowed; the remaining subjects in each condition were instructed to read the statement of the problem situation three times.

Following the presentation of the statement of the problem situation, each subject was provided a set of items of information which was to be used in the solution of the problem. The set of informational items employed in Experiment II was structured in such a way that each subject was allowed to use either of two possible solution strategies.

Hypotheses. These manipulations of the problem materials were brought about to test several hypotheses concerning the use of acquired information in the process of solving a problem.

The findings of Dooling and his associates (Dooling & Lachman, 1971; Dooling & Mullet, 1973) and Bransford and Johnson (1972, 1973) have indicated that when a subject is provided an appropriate thematic cue for a prose passage, he is better able to comprehend and remember

that passage than when no contextual cue is provided. Greeno (1973) and his co-workers (Kieras & Greeno, 1975; Mayer & Greeno, 1975) have similarly manipulated the availability of contextual information in a problem-solving paradigm. These researchers have required subjects to memorize either a set of meaningful or a set of nonmeaningful equations, and to solve a problem using the information contained in those equations. Consistent with the expectation that meaningful equations result in superior comprehension and storage of information, Mayer and Greeno found that those subjects who received the meaningful equations were able to use the information contained in the equations more efficiently than were those subjects who were presented the nonmeaningful equations. As a result, the former subjects exhibited superior problem-solving performance.

It has been similarly suggested by Bransford and Johnson (1972, 1973) and by Greeno (1973) that these findings are related to the availability of previously acquired cognitive knowledge in the interpretation and storage of the incoming information. If the incoming material is semantically meaningful (e.g., appropriate contexts or meaningful equations have been provided), then subjects are able to relate this material to their existing knowledge of the world. As a result, they will be better able to detect incomplete information (Greeno, 1973; Paige & Simon, 1966) and to transform the presentation format of the information (Mayer & Greeno, 1975) than will subjects who are unable to relate the new information to their present cognitive structures.

The following two hypotheses were therefore proposed:

a) When a contextual cue is not provided in the statement of the problem situation, then those subjects who are provided complete information (i.e., are allowed to use either of the two possible solution strategies) exhibit better Efficiency Scores and less total time to solution than do those subjects who are presented incomplete information (i.e., are allowed to use only one of the two solution strategies). When a context is provided in the statement of the problem situation, however, then there is no difference in the Efficiency Scores and the total time to solution of those subjects who are allowed to use either of the solution strategies and those subjects who are allowed to use only one of the strategies.

b) When the items of information provided are expressed in terms of negative statements, Efficiency Scores and total time to solution are poorer than when the informational items are expressed in terms of positive sentences. The difference, however, between the performance of those subjects who are presented the negative statements and those who receive the positive sentences is less when a contextual cue is provided in the statement of the problem situation than when it is not.

Kintsch and Monk (1972) obtained data which indicate that if an individual is given sufficient time to process the information in a prose passage, then the representation of that information in memory is independent of the complexity of the original passage. The following hypothesis was therefore proposed:

c) When subjects are allowed to read the statement of the

problem situation only once, then those subjects who are presented the complex statement of the problem situation exhibit poorer Efficiency Scores and longer total time to solution than do those subjects who are given the simple version of the problem situation. When subjects are allowed to read the statement of the problem situation three times, however, there is no difference in the Efficiency Scores and the total time to solution for those subjects given the complex version of the problem situation and those given the simple statement of the problem situation.

The availability of contextual information has been shown to be an important variable in the comprehension and retention of prose materials. Bransford and Johnson (1972, 1973) and Dooling and Mullet (1973) have obtained data which indicate that contextual information aids recall more if it is available at the time of input than if it is provided at the time of recall. In fact, subjects who were given the context at the time of recall performed little better than did those subjects who did not receive any contextual information. The following hypothesis derives from these findings:

d) Those subjects who are provided the contextual cue before reading the statement of the problem situation display better Efficiency Scores and less total time to solution than do either those subjects who are given the contextual cue after reading the statement of the problem situation or those subjects who are never provided the appropriate context for the problem.

CHAPTER II

METHOD

Subjects

The subjects were 161 Loyola University students who ranged in age from 18 to 30. Of these subjects, 13 were not able to solve at least one of the two practice problems and were therefore excluded from the analyses. Four of the remaining subjects successfully solved each of the practice problems, but were rejected when they responded on the experimental problem by first selecting all of the relevant items of information and then deciding which of those informational items were needed in order to solve the problem, thus distorting their Efficiency Scores as a measure of their problem solving efficiency. Forty-eight subjects participated in Experiment I and 96 subjects participated in Experiment II. Each subject was tested individually in a session which lasted approximately 20 min..

Materials

A deck of 3" X 5" index cards was used to present each problem situation. At the top of an accompanying 9" X 11" display board (Figure 1) was the statement of the problem that was to be solved. Beneath the problem statement, a set of interrogative probes pertaining to the problem situation were displayed. These interrogative probes were questions, the answers to which could be used to solve the problem. The probes were presented on long narrow inserts which were placed in slots in the display board in such a way that the questions were

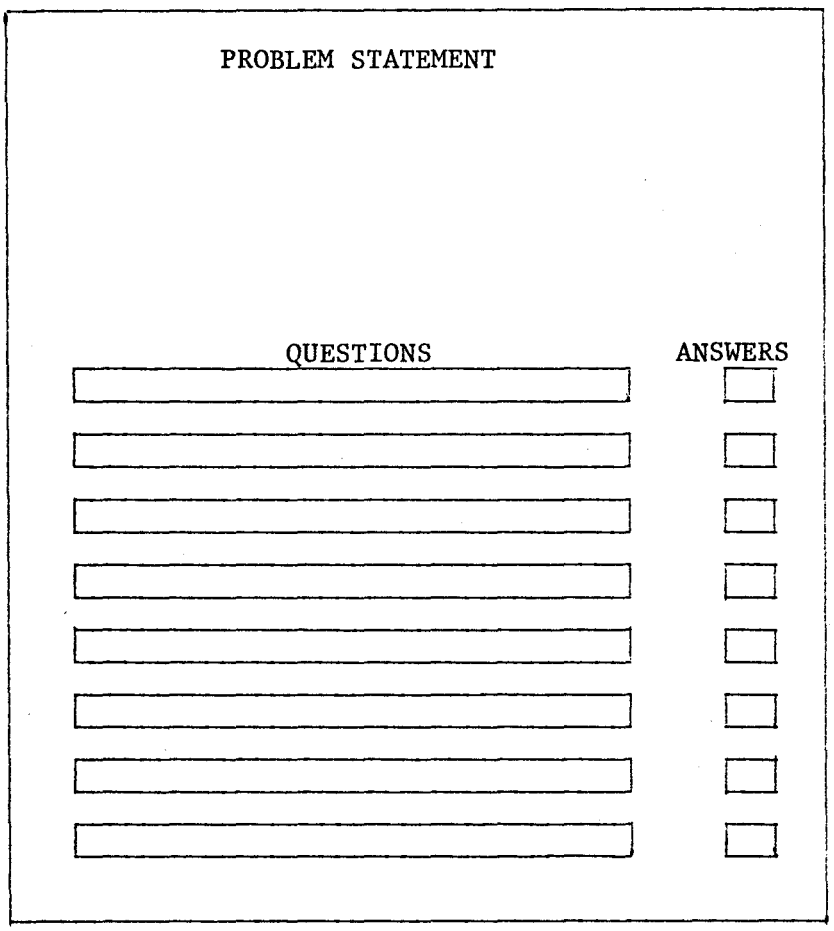

Figure 1. Diagram of the display board.

visible through narrow rectangular windows. To the right of each interrogative probe was located its appropriate answer. Each answer was placed in such a manner that it was not visible until the insert on which its corresponding interrogative probe was presented was pulled approximately ½ in. to the right, at which time the answer appeared in a small square window in the display board.

Score sheets were used which allowed the experimenter to record for each subject the number of interrogative probes selected, the total time needed to obtain the solution to the problem, the time required for the formulation of the solution strategy, the inter-probe latencies, and the final problem solution that was given.

The timing device used was a Sodeco impulse counter which registered 10 impulses per sec. from an impulse generator. The desired time intervals were printed out by the counter onto a tape. The experimenter was able to regulate the counter print-out with a control box interfaced with the timing device.

Procedure

General. In Experiment I and Experiment II each subject was required to attempt the solution of three problems. For each of these problems, the problem situation was presented on a series of index cards. One sentence (or one phrase) was typed on each card, and subjects were paced through the deck at a rate of seven sec. per card. The statement of each problem and the interrogative probes pertaining to the problem were presented on separate display boards.

The first two problems presented to each subject were practice problems. The first of these (Table 1) was based upon a situation in

TABLE 1

PRACTICE PROBLEM I

Problem Situation

Card 1: Several students were enrolled in an introductory fine arts course at Loyola last semester.

Card 2: Some of these students were males and some were females.

Card 3: Only two grades were given in the course, either pass or fail.

Problem Statement

How many males passed the course?

Interrogative Probes	Answers
How many students were enrolled in the course?	63
How many tests were given in the course?	3
How many students passed the course?	49
How many students failed the course?	14
How many males were enrolled in the course?	40
How many times a week did the class meet?	3
How many females were enrolled in the course?	23
How many females failed the course?	4

which there are two attributes (i.e., sex and achievement of students) with two values per attribute (i.e., male-female; pass-fail). The second practice problem (Table 2) was similarly constructed from a situation consisting of two attributes (i.e., color and objective of airplanes) with two values per attribute (i.e., silver or white planes; awaiting either take-off or landing instructions).

If a subject successfully solved each of these initial problems, he was asked to solve a third problem which was based upon a situation in which there are two attributes (i.e., print and consistency of objects) with three and two values per attribute, respectively (i.e., solids, patterns, and whites; delicates and durables). The phrasing of this problem situation, the number of times that it was presented, and the wording and function of the interrogative probes accompanying it were manipulated in order to construct the experimental treatment conditions in Experiment I and Experiment II.

Experiment I. Subjects were shown one of two presentations of the experimental problem situation. Half of the subjects received a version of the problem situation in which thematic information about the problem was omitted (Table 3). The remaining subjects were provided the appropriate context for the problem. These latter subjects received the same problem situation as is presented in Table 3, except that the first card was changed to read, "Washing clothes is actually quite simple." The statements describing the problem situation were typed individually on index cards, and each subject in the context and no-context conditions was presented the appropriate deck of cards three times at a rate of seven sec. per card.

TABLE 2

PRACTICE PROBLEM II

Problem Situation

Card 1: There were several planes awaiting instructions at Midway Airport last Monday.

Card 2: Some of these planes were silver and some were white.

Card 3: Some of the silver planes were on the ground awaiting take-off instructions and some were in the air awaiting landing instructions.

Card 4: Some of the white planes were on the ground awaiting take-off instructions and some were in the air awaiting landing instructions.

Problem Statement

How many white planes were on the ground awaiting take-off instructions?

Interrogative Probes	Answers
How many planes were there altogether awaiting instructions?	25
How many non-silver planes were not on the ground awaiting take-off instructions?	5
How many silver planes were on the ground awaiting take-off instructions?	10
How many non-white planes were awaiting instructions?	14
How many people were waiting to board a plane at the airport?	987
How many silver planes were in the air awaiting landing instructions?	4
Were weather conditions poor that day?	Yes
How many planes awaiting instructions were not on the ground awaiting take-off instructions?	9

TABLE 3

EXPERIMENTAL PROBLEM SITUATION

WITHOUT THE CONTEXTUAL CUE

Card 1:	The procedure is actually quite simple.
Card 2:	You may have to go somewhere else if the proper facilities are not available.
Card 3:	Otherwise, you are ready to begin.
Card 4:	Once the facilities are available, you arrange objects into different groups depending upon their makeup.
Card 5:	You could arrange them into solids, patterns, and whites.
Card 6:	One grouping might be sufficient, though, depending on how much must be done.
Card 7:	But it is important not to overdo things.
Card 8:	That is, it is better to try too few objects at once than too many.
Card 9:	Therefore you might want to further divide the objects into delicate and durable groupings.
Card 10:	At first the whole procedure will seem complicated.
Card 11:	But soon it will become just another fact of life.

After reading the description of the problem situation three times, the deck of index cards was taken from the subject and he was given the problem display board. At the top of this display board was presented the following instructions: "The objects were placed in the groups that were just described. Using the information below, determine: How many objects were there altogether?" Below these instructions on the display board were presented interrogative probes which could be used to solve the problem. The wording of these interrogative probes was manipulated such that half the subjects in each of the context and the no-context conditions were presented interrogative probes which were stated in terms of positive sentences. The positively-worded interrogative probes which were used are listed in Table 4. The remaining subjects received interrogative probes of equivalent meaning, but these probes were presented in terms of negative sentences (Table 5).

Eight interrogative probes were presented to each subject. Three distinct sets of eight interrogative probes were used. The collective properties of the interrogative probes in each of these three sets constituted the functional manipulation of the solution availability. The uniqueness of these sets evolved from the fact that different types of strategies and numbers of solutions were allowed by the interrogative probes in each set. One of the sets allowed the use of either of two solution strategies (i.e., "complete" information was provided), while each of the remaining two sets allowed the use of only one of the two strategies (i.e., "incomplete" information was provided). To illustrate, there are two possible solution strategies if the interrogative probes "A" through "G" from Table 4 or Table 5 accompany the problem statement

TABLE 4

LIST OF POSSIBLE INTERROGATIVE

PROBES: POSITIVE WORDING

	Interrogative Probes	Answers
A	How many delicate objects were placed in the solid group?	13
B	How many delicate objects were placed in the white group?	9
C	How many durable objects were there?	50
D	How many delicate objects were placed in the patterned group?	17
E	How many durable objects were placed in the patterned group?	15
F	How many objects were placed in the solid groups?	36
G	How many objects were placed in the white groups?	21
H	How many groups of objects were there?	6
I	How long did it take to place the objects into the groups?	15 min.

TABLE 5

LIST OF POSSIBLE INTERROGATIVE

PROBES: NEGATIVE WORDING

Interrogative Probes		Answers
A	How many non-durable objects were not placed in the patterned group not the white group?	13
B	How many non-durable objects were not placed in the solid group nor the patterned group?	9
C	How many non-delicate objects were there?	50
D	How many non-durable objects were not placed in the solid group nor the white group?	17
E	How many non-delicate objects were not placed in the solid group nor the white group?	15
F	How many objects were not placed in the patterned group nor the white group?	36
G	How many objects were not placed in the solid group nor the patterned group?	21
H	How many groups of objects were there?	6
I	How long did it take to place the objects into the groups?	15 min.

on the display board:

a) The subject may first find out how many durable objects there were ("C"). Once this information has been obtained, the subject only has to find out how many delicate objects there were in order to solve the problem. This value may be determined by adding together the number of delicate objects in the solid group ("A"), delicate objects in the white group ("B"), and delicate objects in the patterned group ("D"). By then adding the number of durable objects and the number of delicate objects the subject may determine the total number of objects.

b) By adding the number of delicate objects in the patterned group ("D") and the number of durable objects in the patterned group ("E"), the subject may determine the number of objects in the patterned groups. This value may then be added to the number of objects in the solid groups ("F") and the number of objects in the white groups ("G") in order to determine the total number of objects.

However, if the probe "A" in the present illustration is replaced by probe "H", it is no longer possible to determine the number of delicate objects in the solid group. As a result, the use of the first of the two solution strategies listed above is nullified. Similarly, if probe "H" replaces probe "E", the use of the second solution strategy is prohibited, since the number of durable objects in the patterned group is no longer attainable. (Probe "I" is a filler probe which is not relevant to the solution of the problem. It was randomly presented with the other interrogative probes, thus filling out each set so that eight

probes were presented to each subject.)

Half the subjects in each of the context-positive wording, context-negative wording, no-context-positive wording, and no-context-negative wording conditions discussed above were provided interrogative probes which were complete (i.e., they were presented probes "A" through "G", which allowed the use of either of the two solution strategies). The remaining subjects in each condition were presented interrogative probes which were incomplete (i.e., they allowed the use of only one of the two solution strategies. Half of these latter subjects received probes "B" through "H", while the remaining subjects received probes "A" through "D" and "F" through "H".

Six randomly assigned subjects participated in each of the eight treatment conditions which resulted from the manipulation of the independent variables. These variables, along with the resultant eight treatment conditions, are presented in Table 6.

Experiment II. One of two versions of the experimental problem situation was presented to each subject. Half of the subjects received a simple version of the problem situation. This simple version was the same as that seen by the subjects in Experiment I (Table 3). The remaining subjects were presented a complex version (Table 7), which was constructed through the use of numerous grammatical and syntactic transformations of the simple version, and it described the problem situation in one long sentence. Care was taken to use semantically equivalent expressions in the two versions of the problem situation whenever possible, and the two versions were equated for number of words used.

One third of the subjects in each of the simple and complex

TABLE 6

INDEPENDENT VARIABLES AND RESULTANT

EIGHT TREATMENT CONDITIONS IN EXPERIMENT I

Availability of the Context	Wording of the Interrogative Probes	Completeness of the Interrogative Probes	Condition
Context (C)	Positive (P)	Complete (T)	C P T
		Incomplete (I)	C P I
	Negative (N)	Complete (T)	C N T
		Incomplete (I)	C N I
No Context (X)	Positive (P)	Complete (I)	X P T
		Incomplete (I)	X P I
	Negative (N)	Complete (T)	X N T
		Incomplete (I)	X N I

TABLE 7

COMPLEX VERSION OF EXPERIMENTAL

PROBLEM SITUATION

Card 1:	The procedure is actually quite simple
Card 2:	once the proper facilities are available,
Card 3:	although you may have to go somewhere else if the necessary facilities are not available,
Card 4:	when you begin by arranging objects into different groups depending upon their makeup,
Card 5:	possibly arranging them into solids, patterns, and whites;
Card 6:	but since it is important not to overdo things,
Card 7:	while one grouping might be sufficient depending on how much must be done,
Card 8:	it is better to try too few objects at once than too many,
Card 9:	which may mean that you will want to further divide the objects into delicate and durable groupings,
Card 10:	which may make the whole procedure seem complicated,
Card 11:	but soon it will become just another fact of life.

conditions was verbally provided the appropriate context by the experimenter before reading the statement of the problem situation. Another third of the subjects in each of the simple and complex conditions was presented the contextual cue by the experimenter after the statement of the problem situation had been read, but before the problem to be solved was received. For the remainder of the subjects, no contextual information was provided.

Each statement in the simple and complex versions of the problem situation was typed on a separate index card, and each card was presented for seven sec. For half the subjects in each of the six categories generated by the factorial crossing of paragraph complexity and availability of contextual cue, the deck of cards describing the experimental problem situation was presented only once. The remaining subjects were paced through the deck of cards three times.

After the subject was allowed either one or three readings of the experimental problem situation, the deck of index cards was collected by the experimenter, and the subject was given the problem display board. The instructions at the top of this display board were the same as those employed in Experiment I. Below these instructions on the display board were presented interrogative probes that were to be used in the solution of the problem. The collective properties of the interrogative probes employed in Experiment II were such that each subject was allowed the use of either of the two possible solution strategies.

Eight randomly assigned subjects participated in each of the resultant 12 treatment conditions. The interrelationships of the independent variables and the 12 treatment conditions are presented

in Table 8.

Scoring

Each subject was free to choose the number and the order of the interrogative probes he wished to have answered in solving the problem, but he was cautioned in the instructions to make his probe selections carefully. (The instructions, as they were tape recorded and played for each subject are presented in Appendix I.) Thus the experimenter was able to observe directly the strategy employed by each subject as it was demonstrated by the sequence of interrogative probes chosen to be answered. (It is, of course, a necessary assumption here that the strategy displayed by a subject on any given problem does indeed reflect his implicit search, evaluation, and subsequent utilization of the available information.) It has been assumed that an ideal strategy for the solution of the problem does exist, and that this ideal strategy is that selection of probes which accumulates the information needed to solve the problem in the most parsimonious manner, i.e., without the selection of interrogative probes which provide irrelevant, redundant, or otherwise unusable information. To the extent that a subject's solution strategy approaches this ideal strategy, the number of probes selected will decrease, with a minimum of four interrogative probes for problem solution. The number of interrogative probes selected by each subject was interpreted as his Efficiency Score.

In addition to this Efficiency Score, measures of problem-solving performance were obtained by observing for each subject the total time needed to obtain the solution to the problem, the time required for the preparation of the solution strategy (i.e., the time which elapsed

TABLE 8

INTERRELATIONSHIPS OF THE INDEPENDENT VARIABLES AND RESULTANT 12 TREATMENT CONDITIONS

Complexity of the Problem Situation	Presentation of the Context in the Problem Situation	Number of Readings of the Problem Situation	Condition
Simple (S)	Before (B)	One (O)	S B O
		Three (T)	S B T
	After (A)	One (O)	S A O
		Three (T)	S A T
	Not At All (N)	One (O)	S N O
		Three (T)	S N T
Complex (C)	Before (B)	One (O)	C B O
		Three (T)	C B T
	After (A)	One (O)	C A O
		Three (T)	C A T
	Not At All (N)	One (O)	C N O
		Three (T)	C N T

between the presentation of the display board and the first probe selection), the inter-probe latencies (i.e., the time which elapsed between probe selections), and the accuracy of the problem solution that was offered. The subjects were not told that they were being timed.

CHAPTER III

RESULTS AND DISCUSSION

Experiment I

A 2^3 ANOVA was computed on the total time data. The results of this analysis are summarized in Table 9. The F-ratios for the context by wording and context by completeness interactions are less than unity, thus not supporting the first two hypotheses stated above. Significance was obtained for the main effects of context, wording, and completeness. The mean and median total times to solution for each group involved in these main effects are presented in Table 10. Those subjects who were given a context in the statement of the problem situation required less time to solve the problem than did those subjects who were not presented a context. The positive wording of the interrogative probes resulted in less total time to solution than did the negative wording of the probes. Those subjects who received interrogative probes which provided incomplete information (i.e., allowed the use of only one of the two possible solution strategies) required more time to solve the problem than did those subjects who were provided complete information (i.e., allowed the use of either of the two possible solution strategies). These findings are consistent with preexperimental expectations.

Summarized in Table 11 are the results of a 2^3 ANOVA computed on the Efficiency Score data. The main effects of context, wording, and completeness, as well as the second order interaction of these three variables, are significant. The context by wording by completeness

TABLE 9

ANALYSIS OF VARIANCE FOR TOTAL

TIME DATA: EXPERIMENT I

Source of Variance	SS	df	MS	F
Context (X)	457078.8	1	457078.8	6.77 *
Wording (W)	1307852.0	1	1307852.0	19.38 ****
Completeness (C)	467208.2	1	467208.2	6.92 *
X by W	7874.0	1	7874.0	
X by C	164476.1	1	164476.1	2.44
W by C	5293.8	1	5293.8	
X by W by C	98729.9	1	98729.9	1.46
Error	2698715.0	40	67467.9	

*p<.05

****p<.001

TABLE 10

MEAN AND MEDIAN TOTAL TIME TO

SOLUTION: EXPERIMENT I

Condition	Mean	Median	SD
Context	332.04	221.35	262.34
No Context	527.21	541.80	371.09
Positive	264.56	195.15	203.59
Negative	594.69	619.35	357.89
Incomplete	528.29	502.20	360.10
Complete	330.97	217.90	276.43

TABLE 11

ANALYSIS OF VARIANCE FOR EFFICIENCY

SCORE DATA: EXPERIMENT I

Source of Variance	SS	df	MS	F
Context (X)	5.33	1	5.33	4.64 *
Wording (W)	5.33	1	5.33	4.64 *
Completeness (C)	27.00	1	27.00	23.48 ****
X by W	0.33	1	0.33	
X by C	0.33	1	0.33	
W by C	1.33	1	1.33	1.16
X by W by C	5.33	1	5.33	4.64 *
Error	45.99	40	1.15	

*p<.05

****p<.001

interaction is illustrated in Figure 2. The results of tests for simple interaction effects and simple simple main effects (Kirk, 1968, pp. 222-224) in this interaction are summarized in Table 12. The results of these tests indicate that the context by wording by completeness interaction is primarily due to differences in the completeness variable when no context and positive wording are presented. Subjects who were provided incomplete information without a context and with positive wording required more interrogative probes in order to solve the problem than did those subjects who were given no context and positive wording, but who were provided information which was complete.

Inspection of subjects' inter-probe latencies has suggested that much of this context by wording by completeness interaction in the Efficiency Score data was a function of random factors operating in subjects' initial probe selections. The probe-selection protocols for most subjects indicated large latencies between probe selections. This was true even for the majority of those subjects who solved the problem with the minimum of four probe selections. These large inter-probe latencies suggest that few subjects covertly executed a solution strategy to completion prior to the initial probe selection. As a result, if a subject was presented a set of interrogative probes in which only one of the two solution strategies was possible, his subsequent performance was largely dependent upon his initial probe selection. If the strategy for which complete information was available was initially attempted by a subject, then he needed fewer interrogative probes in order to solve the problem. However, if a subject's initial attempt to solve the problem used the strategy for which the information

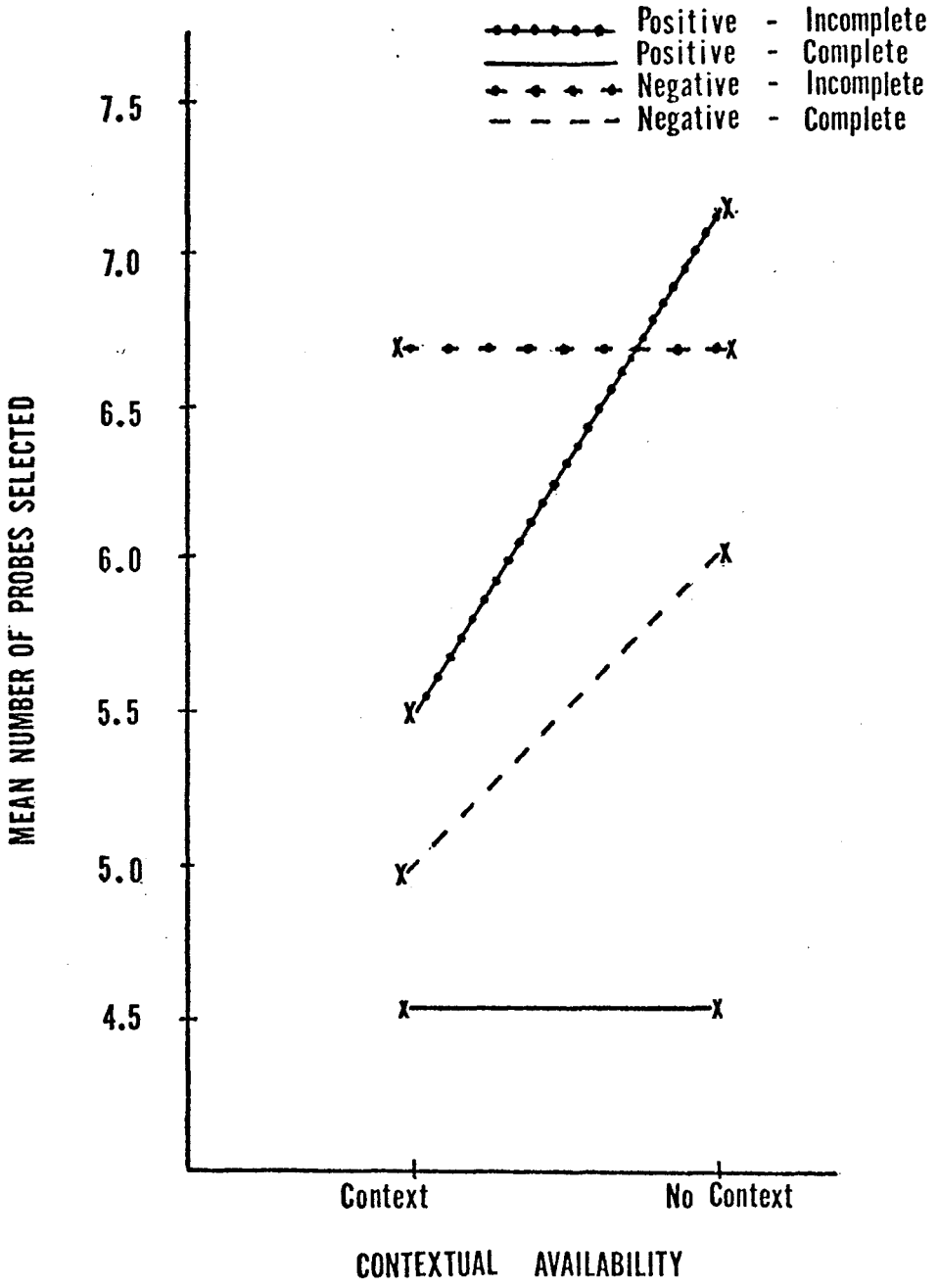

Figure 2. Context by wording by completeness interaction for the Efficiency Score data: Experiment I.

TABLE 12

SIMPLE SIMPLE MAIN EFFECTS AND SIMPLE INTERACTION EFFECTS IN THE CONTEXT BY WORDING BY COMPLETENESS INTERACTION FOR THE EFFICIENCY SCORE DATA: EXPERIMENT

Source of Variance	SS	df	MS	F
Context (X)	5.33	1	5.33	4.64 *
X at WC_{11}	8.34	1	8.34	7.25 *
X at WC_{12}	0.00	1	0.00	
X at WC_{21}	0.00	1	0.00	
X at WC_{22}	3.00	1	3.00	2.61
Wording (W)	5.33	1	5.33	4.64 *
W at XC_{11}	4.09	1	4.09	3.56
W at XC_{12}	0.75	1	0.75	
W at XC_{21}	0.75	1	0.75	
W at XC_{22}	6.75	1	6.75	5.87 *
Completeness (C)	27.00	1	27.00	23.48 ****
C at XW_{11}	3.00	1	3.00	2.61
C at XW_{12}	8.34	1	8.34	7.25 *
C at XW_{21}	21.34	1	21.34	18.56 ****
C at XW_{22}	1.34	1	1.34	1.17

TABLE 12 (CONTINUED)

SIMPLE SIMPLE MAIN EFFECTS AND SIMPLE INTERACTION EFFECTS IN THE CONTEXT BY WORDING BY COMPLETENESS INTERACTION FOR THE EFFICIENCY SCORE DATA: EXPERIMENT I

Source of Variance	SS	df	MS	F
XW at C_1	4.16	1	4.16	3.62
XW at C_2	1.50	1	1.50	1.30
XC at W_1	4.18	1	4.18	3.63
XC at W_2	1.50	1	1.50	1.30
WC at X_1	0.50	1	0.50	
WC at X_2	5.66	1	5.66	4.20 *
Error	45.99	40	1.15	

*$p<.05$

****$p<.001$

X_1 = Context

X_2 = No Context

W_1 = Positive Wording

W_2 = Negative Wording

C_1 = Incomplete Information

C_2 = Complete Information

provided was incomplete, he was subsequently forced to select more than the minimum number of probes needed for problem solution, thus raising the value of his Efficiency Score. Further support for this suggestion that the initial probe choices are the result of random selections rather than the careful consideration of the available information derives from the fact that of the 24 subjects in Experiment I who were provided complete information, 11 subjects initially selected probes which could be used in one of the strategies, while the remaining 13 subjects initially selected probes which could be used in the other solution strategy. By chance, one would expect 12 subjects to initially select probes from each of the possible solution strategies. Pearson's χ^2 test for goodness of fit supported the suggestion of randomness in these findings [$\chi^2(1) = 0.083$, $p>.80$]. Furthermore, if the initial probe selections are random, then for those subjects who were provided incomplete information, one would expect the number of subjects initially selecting probes which could be used in the permissible strategy to equal the number of subjects initially selecting probes from the non-permissible strategy. Consistent with this conjecture, Pearson's χ^2 test of association indicated randomness in the initial probe selections [$\chi^2(1) = 0.166$, $p>.60$]. These findings, along with the fact that the majority of the subjects (40 out of 48) continued in the solution strategy from which the initial probes were selected, further confirm the assertion that the Efficiency Scores of those subjects who were provided incomplete information were largely determined by random factors operating in the initial probe selections. As a result, further analyses of the data from Experiment I have been disregarded.

Pearson χ^2 tests of association were planned to evaluate the effect of the context, wording, and completeness variables upon the solution accuracy data. However, the solution rates approached unity (i.e., only eight subjects failed to solve the problem), which resulted in expected frequencies too small for legitimate tests.

Experiment II

A 2 x 2 x 3 ANOVA was done on the total time data, the results of which are summarized in Table 13. The predicted main effect of context is not significant. However, the main effects of paragraph complexity and reading time, and the interaction of these two variables, are significant. The complexity by reading time interaction is illustrated in Figure 3. Tests for simple main effects, the results of which are summarized in Table 14, indicate that this interaction is primarily due to the total time to solution required by those subjects in the complex paragraph-one reading condition. These subjects required significantly more total time in order to solve the problem than did the subjects in the other three conditions. Performance in these latter three conditions did not differ in themean total time to solution.

The results of a 2 x 2 x 3 ANOVA which was computed on the Efficiency Score data are summarized in Table 15. While the predicted main effect of context is not significant, the main effect of reading time and the interaction of paragraph complexity by reading time are significant. The complexity by reading time interaction is represented in Figure 4. The results of tests for simple main effects (Table 16) indicate that this interaction is mainly due to the number of probe selections required for solution by those subjects in the complex para-

TABLE 13

ANALYSIS OF VARIANCE FOR TOTAL

TIME DATA: EXPERIMENT II

Source of Variance	SS	df	MS	F
Complexity (C)	47926.44	1	47926.44	5.82 *
Reading Time (R)	145984.60	1	145984.60	17.72 ****
Context (X)	1114.43	2	557.21	
C by R	120911.50	1	120911.50	14.68 ****
C by X	2251.67	2	1125.83	
R by X	30256.76	2	15128.38	1.84
C by R by X	6687.89	2	3343.94	
Error	691903.90	84	8236.95	

*$p<.05$

****$p<.001$

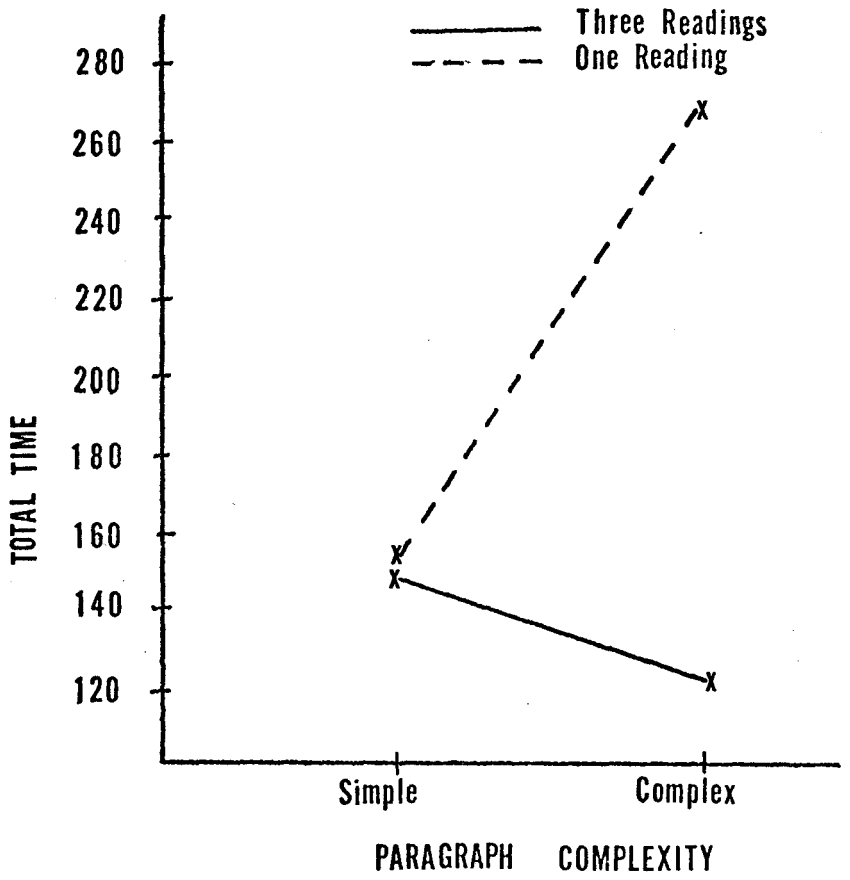

Figure 3. Paragraph complexity by reading time interaction for the total time data: Experiment II.

TABLE 14

SIMPLE MAIN EFFECTS IN THE COMPLEXITY BY READING TIME INTERACTION FOR THE TOTAL TIME DATA: EXPERIMENT II

Source of Variance	SS	df	MS	F
Complexity (C)	47926.44	1	47926.44	5.82 *
C at R_1	160554.59	1	160554.59	19.49 ****
C at R_2	8300.28	1	8300.28	1.01
Reading Time (R)	145984.60	1	145984.60	17.72 ****
R at C_1	589.68	1	589.68	
R at C_2	266340.48	1	266340.48	32.34 ****
Error	691903.90	84	8236.95	

*p<.05

****p<.001

C_1 = Simple Paragraph

C_2 = Complex Paragraph

R_1 = One Reading

R_2 = Three Readings

TABLE 15

ANALYSIS OF VARIANCE FOR EFFICIENCY

SCORE DATA: EXPERIMENT II

Source of Variance	SS	df	MS	F
Complexity (C)	1.26	1	1.26	1.18
Reading Time (R)	4.59	1	4.59	4.31 *
Context (X)	2.27	1	1.14	1.06
C by R	17.51	1	17.51	16.41 ****
C by X	1.89	2	0.95	
R by X	6.06	2	3.03	2.84
C by R by X	4.02	2	2.01	1.88
Error	89.62	84	1.07	

*$p<.05$

****$p<.001$

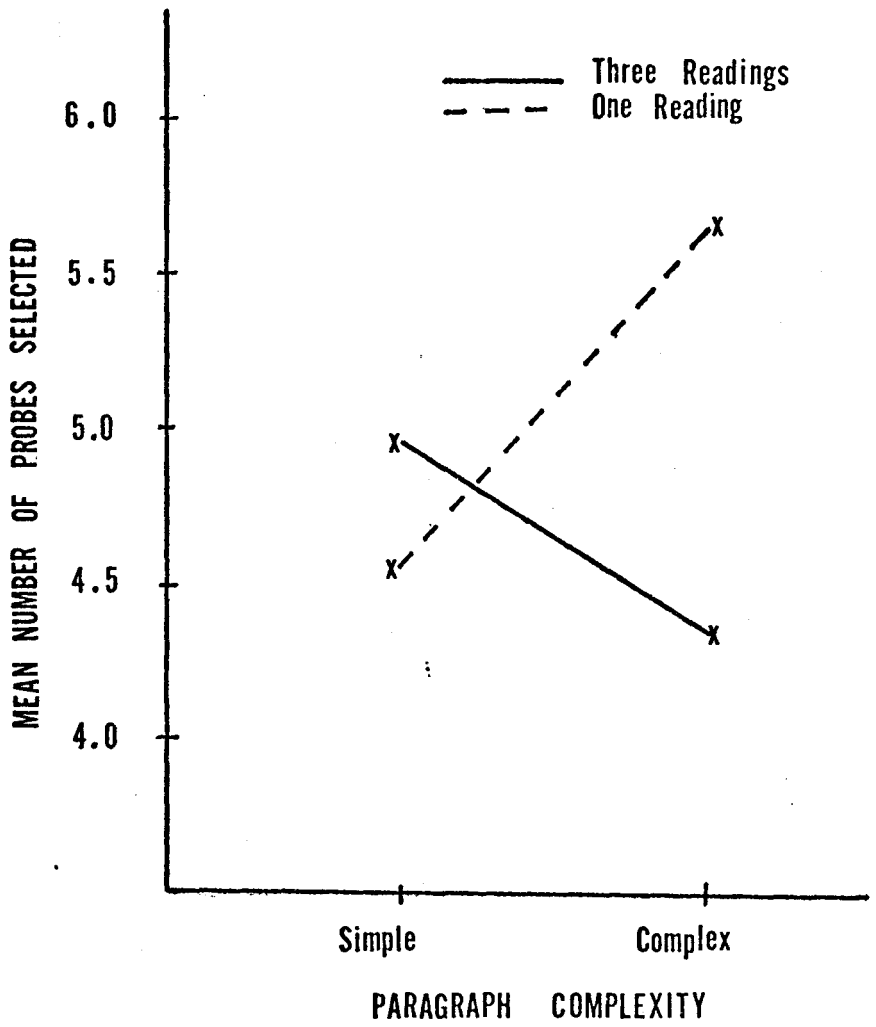

Figure 4. Paragraph complexity by reading time interaction for the Efficiency Score data: Experiment II.

TABLE 16

SIMPLE MAIN EFFECTS IN THE COMPLEXITY BY READING TIME INTERACTION FOR THE EFFICIENCY SCORE DATA: EXPERIMENT II

Source of Variance	SS	df	MS	F
Complexity (C)	1.26	1	1.26	1.18
C at R_1	14.25	1	14.25	13.32 ****
C at R_2	4.76	1	4.76	4.46 *
Reading Time (R)	4.59	1	4.59	4.31 *
R at C_1	2.12	1	2.12	1.99
R at C_2	20.28	1	20.28	19.01 ****
Error	89.62	84	1.07	

*$p<.05$

****$p<.001$

C_1 = Simple Paragraph

C_2 = Complex Paragraph

R_1 = One Reading

R_2 = Three Readings

graph-one reading condition. These subjects required significantly more probe selections than did the remaining subjects.

A Pearson product-moment correlation between the Efficiency Scores and the total time to solution yielded a correlation coefficient of 0.73 [$t(94) = 10.36$, $p<.001$]. This highly significant correlation indicates that as the number of probe selections required for solution increases, the time needed to solve the problem also increases, thus suggesting that the Efficiency Score and total time measures of problem-solving efficiency are covarying. In an effort to eliminate this covariation from the analyses, a 2 x 2 x 3 analysis of covariance (ANACOVA) was computed treating total time as the variate and the Efficiency Scores as the covariate. In this way, the effect of the experimental manipulations upon total time was measured independent of the concomitant variation of the Efficiency Score measure. The results of this ANACOVA are summarized in Table 17. Significance was obtained for the main effects of paragraph complexity and reading time. Those subjects who were presented the simple paragraph describing the problem situation required a mean adjusted total time to solution of 2.64 min., while the subjects who were presented the complex paragraph required a mean adjusted total time of 3.17 min. The mean adjusted total time taken by subjects in the one reading and three reading conditions were 3.34 min. and 2.47 min., respectively. The highly significant paragraph complexity by reading time interaction obtained in the ANOVA on the total time data, however, was not found in the present ANACOVA. The mean adjusted total time required by those subjects in each of the conditions generated by the factorial crossing of paragraph complexity

TABLE 17

ANALYSIS OF COVARIANCE TREATING TOTAL TIME AS VARIATE AND EFFICIENCY SCORE AS COVARIATE: EXPERIMENT II

Source of Variance	SS	df	MS	F
Complexity (C)	23208.69	1	23208.69	4.98 *
Reading Time (R)	62835.00	1	62835.00	13.49 ****
Context (X)	4567.50	2	2283.75	
C by R	8969.50	1	8969.50	1.93
C by X	1166.13	2	583.06	
R by X	6216.38	2	3108.19	
C by R by X	1372.44	2	686.22	
Covariate	305172.56	1	305172.56	65.50
Error	386730.94	83	4659.41	

*$p<.05$

****$p<.001$

and reading time is illustrated in Figure 5. A comparison of the contents of this figure with the illustration presented in Figure 3 demonstrates the survival of themain effects of paragraph complexity and reading time, and the deterioration of the interaction of these two variables. A similar ANACOVA was computed treating the Efficiency Scores as the variate and total time as the covariate. No significant effects were obtained from this analysis.

Supplementary analyses were done on the proportions of the total time spent in preparation, i.e., the proportion of the total time which elapsed between the presentation of the display board and the first probe selection. A Pearson product-moment correlation between these proportions and total time yielded a highly significant correlation coefficient [$r = -0.54$, $t(94) = 6.22$, $p<.001$], as did a correlation between these proportions and the Efficiency Scores [$r = -0.62$, $t(94) = -7.66$, $p<.001$]. These analyses indicate that as the proportion of the total time spent in preparation increased, the total time and Efficiency Score values decreased (i.e., as the proportion of the total time spent in preparation increased, problem-solving performance improved). The proportions of the total time spent in preparation were further analyzed by correlating these values with the total time residuals resulting from the regression of total time on the Efficiency Scores. In this way, the correlation between the proportion of the total time spent in preparation and total time, statistically independent of the effects of the Efficiency Score measure, was evaluated. This correlation coefficient was found to be significant [$r = -0.12$, $t(94) = -1.18$, $p>.25$].

An ANACOVA was computed treating the proportions of the total time

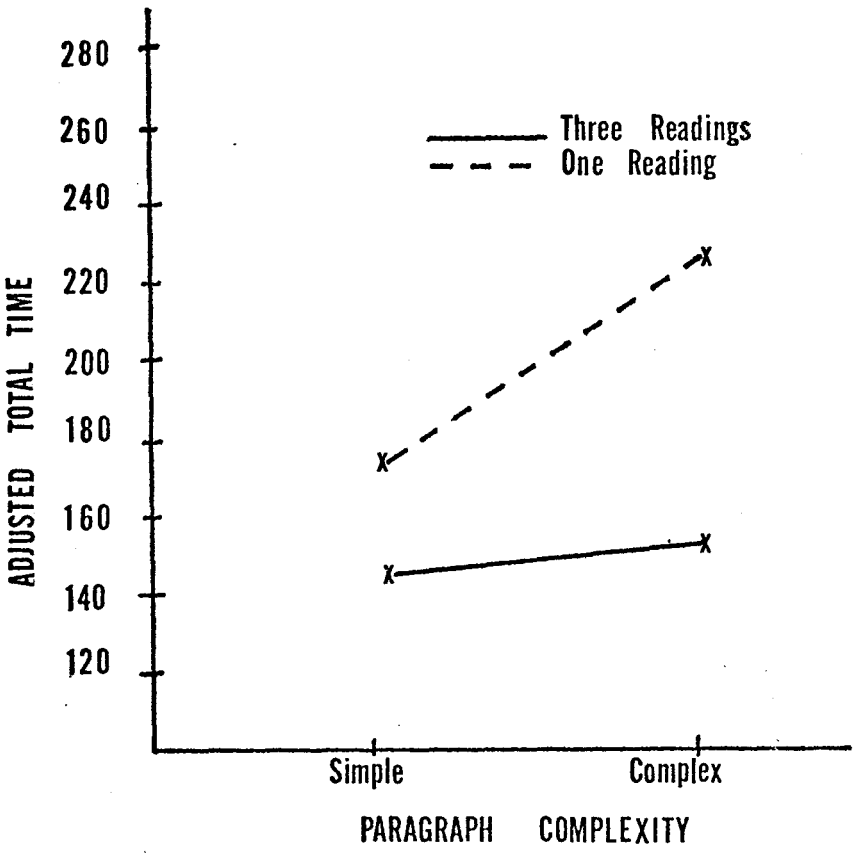

Figure 5. Mean adjusted total time for subjects in the conditions generated by the factorial crossing of paragraph complexity and reading time: Experiment II.

spent in preparation as the variate and treating total time and the Efficiency Scores as covariates. The results of this ANACOVA are summarized in Table 18. The main effect of reading time and the interaction effect of reading time by context are significant. The reading time by context interaction is represented in Figure 6. The results of tests for simple main effects in this interaction are summarized in Table 19. Performance was equivalent in all conditions except when subjects were presented the contextual cue follwoing three readings of the problem situation. These subjects spent a greater proportion of the total time in preparation than did the remaining subjects.

Pearson χ^2 tests of association were planned in order to evaluate the effects of the experimental manipulations upon the solution accuracy data. Each of the 96 subjects correctly solved the problem, however, which prevented the legitimate use of this statistical technique.

TABLE 18

ANALYSIS OF COVARIANCE TREATING PROPORTION OF TOTAL TIME IN PREPARATION AS VARIATE WITH TOTAL TIME AND EFFICIENCY SCORE AS COVARIATES: EXPERIMENT II

Source of Variance	SS	df	MS	F
Complexity (C)	0.002	1	0.002	
Reading Time (R)	0.176	1	0.176	5.43 *
Context (X)	0.062	2	0.031	
C by R	0.000	1	0.000	
C by X	0.001	2	0.0005	
R by X	0.220	2	0.110	3.38 *
C by R by X	0.060	2	0.030	
Covariates	1.313	2	0.656	20.21
Covariate 1	0.033	1	0.033	1.01
Covariate 2	0.527	1	0.527	16.22
Error	2.663	82	0.033	

*$p<.05$

Covariate 1 = Total Time

Covariate 2 = Efficiency Scores

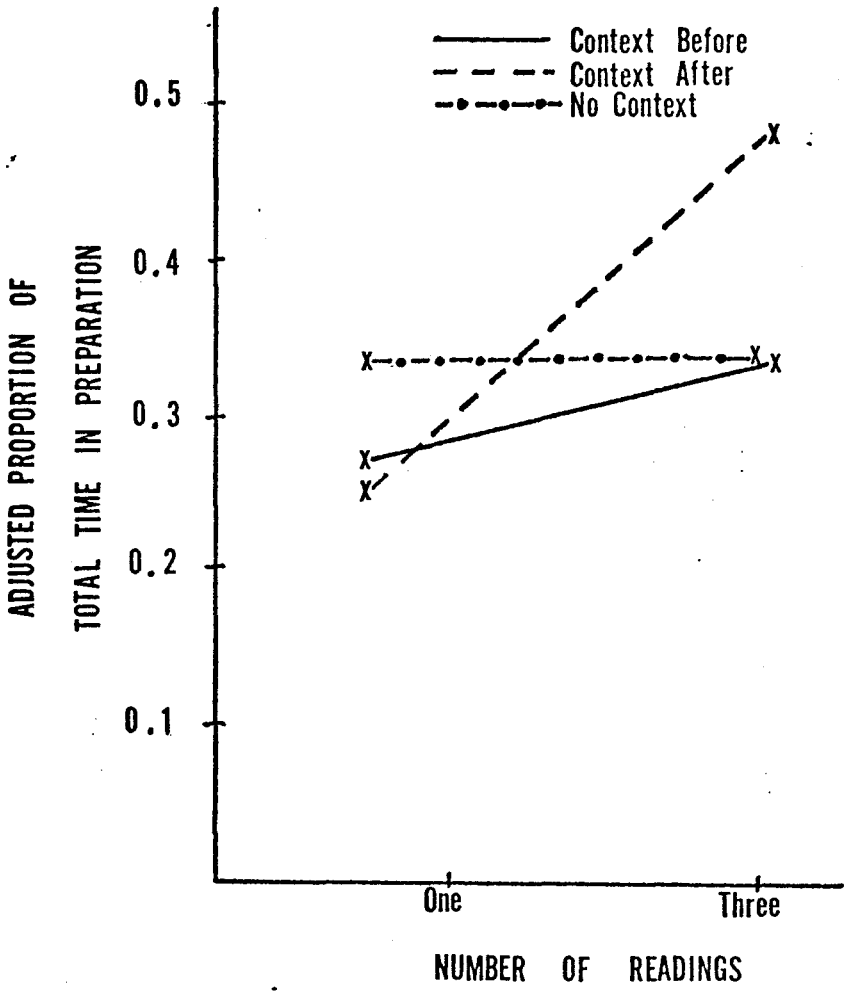

Figure 6. Reading time by context interaction for the adjusted proportions of the total time spent in preparation: Experiment II.

TABLE 19

SIMPLE MAIN EFFECTS IN THE READING TIME BY CONTEXT INTERACTION IN THE ANALYSIS OF COVARIANCE WITH PROPORTION OF TOTAL TIME IN PREPARATION AS VARIATE AND TOTAL TIME AND EFFICIENCY SCORE AS COVARIATES: EXPERIMENT II

Source of Variance	SS	df	MS	F
Reading Time (R)	0.176	1	0.176	5.43 *
R at X_1	0.02	1	0.02	
R at X_2	0.41	1	0.41	12.62 ****
R at X_3	0.00	1	0.00	
Context (X)	0.062	2	0.031	
X at R_1	0.07	2	0.035	1.06
X at R_2	0.21	2	0.105	3.18 *
Error	2.663	82	0.033	

*$p<.05$

****$p<.001$

X_1 = Context Before

X_2 = Context After

X_3 = No Context

R_1 = One Reading

R_2 = Three Readings

CHAPTER IV

GENERAL DISCUSSION

The main effect of completeness of the information in the interrogative probe set was found to be significant for both the total time and the Efficiency Score measures in Experiment I. As was pointed out above, subjects' initial probe choices appear to have been based not upon the careful consideration of the available information, but rather, upon the chance selection of probes prior to any verification that the selected probes could actually be used in the solution of the problem. Similar behavior has been observed by Mayer and Greeno (1975), who found that when presented an unsolvable problem, most subjects proceeded to carry out calculations prior to inspecting the problem materials to determine if a solution could be obtained. As a result of the suspected random nature of the initial probe selections in the present experiment, one can project that differences between the incomplete and the complete conditions may have been inflated, especially for the Efficiency Score measure. Those subjects who were given complete information had a greater chance (from a purely stochastic standpoint) of initially selecting probes which could be used in the solution of the problem than did those subjects who were presented an incomplete set of interrogative probes. Furthermore, among those subjects who were provided incomplete information, if an individual's initial probe selections were from the permissible strategy, his subsequent performance was arbitrarily better than was the performance of

those subjects whose initial attempt to solve the problem employed the strategy for which the information provided was insufficient for solution. Therefore, in view of this presumed randomness in the initial probe selections, interpretations of the results from Experiment I will be made with considerable caution.

As was expected, the main effect of wording in Experiment I is significant for both total time and Efficiency Scores. Due to the transformations and reinterpretations necessary for the comprehension of negative statements, those subjects who were presented interrogative probes which were negatively worded required a greater number of probe selections and more total time in order to solve the problem than did those subjects who were given positive probes.

Contextual availability was also found to be significant for both the total time and the Efficiency Score measures in Experiment I. Those subjects who were provided an appropriate context for the problem in the statement of the problem situation required less total time and fewer probe selections than did those subjects who were not provided a context for the problem. Bransford and Johnson (1972, 1973) have argued that similar effects are due to the fact that a context aids in the interpretation and organization of prose materials such that they may be stored in a manner which is consistent with an individual's existing cognitive knowledge of the world. Mayer and Greeno (1975) similarly contend that meaningful materials facilitate the development of connections between the input materials and information already in an individual's semantic memory (i.e., external connectedness). If such an explanation of contextual facilitation is accurate,

then the context by wording interaction in Experiment I should have been significant (hypothesis b). This predicted interaction was derived from Egan and Greeno (1973) and Mayer and Greeno (1975), in which it was argued that once prose material has been organized and integrated into an individual's existing knowledge structure, the use of that material will be more flexible (thus rendering it more susceptible to transformations and modifications) than if such an organization and integration has not taken place. The context by wording interaction for neither total time nor Efficiency Scores was found to be significant in Experiment I. Furthermore, the main effect of context in Experiment II was found to have no effect upon either of these measures of problem-solving efficiency.

While these null results suggest that the explanations of contextual facilitation offered above may be erroneous, there are several plausible explanations for this lack of clear-cut evidence for contextual facilitation in the present study. The most obvious of these is that qualitative differences in the way in which information is processed and stored when there is a context as opposed to when there is not a context do not exist. In view of the large number of studies which have demonstrated the facilitating effects of contexts upon memory (e.g., Bransford & Johnson, 1972, 1973; Doll & Lapinsky, 1974; Dooling & Lachman, 1971; Dooling & Mullet, 1973) and problem solving (Mayer & Greeno, 1975), however, such an explanation does not seem warranted. An alternate explanation derives from the contention that memory processes are not crucial to problem-solving efficiency. Again, however, numerous studies (e.g., Duncan, 1959; Greeno, 1973; Posner,

1973), as well as one's personal experiences, suggest that such an explanation should not be weighted too heavily. Related to this latter explanation, however, is the contention that there may be many levels at which information may be processed. As several researchers have argued (e.g., Dooling, 1972; Haviland & Clark, 1974; Mistler-Lachman, 1972; Schwartz, Sparkman, & Deese, 1970), while at a deep level of information processing we may remember prose material with respect to a context, there may be a more shallow level of processing in which sentences are understood and remembered, but without the benefit of relating that information to a context. In this respect, it seems reasonable to suspect that the subjects in the present study may well have dealt with the information in the statement of the problem situation at this more shallow level of processing. After solving two practice problems which established the nature of the problem-solving task, the majority of the subjects were likely aware of the type of information in the problem situation which was necessary for problem solution, and that information could easily be retained without the aid of a context. As Bransford and his associates (e.g., Bransford, Barclay, & Franks, 1972; Bransford & Franks, 1971; Bransford & Johnson, 1972, 1973; Johnson, Bransford, & Solomon, 1973) have repeatedly pointed out, a subject's performance depends not only on what he reads, but also on the implications of that information in view of the relevant knowledge he already has. In the present study, the relevant knowledge possessed by many subjects no doubt included the fact that the problem solution could be achieved simply by remembering the specific information about the object groupings, thus eliminating

any need for a deeper, context-dependent processing of the information in the problem situation. While no conclusion concerning this conjecture may be inferred from the present study, subsequent investigations of this phenomenon might include a test of recall for the problem situation following the problem-solving task. Through the results of such a recall test, an estimate of problem-solving efficiency relative to the degree of memory for the problem materials might be obtained. Subsequent investigations using the present methodology might also limit the number of practice problems to one, thereby reducing the extent to which subjects would be primed concerning the requirements of the task.

The predicted (hypothesis c) paragraph complexity by reading time interaction in Experiment II was obtained for both the total time and the Efficiency Score data. However, in neither the ANACOVA whichtreated total time as the variate and Efficiency Score as the covariate nor in the ANACOVA in which total time was the covariate and Efficiency Score was the variate did this complexity by reading time interaction survive. These results suggest that this interaction for both total time and Efficiency Scores is due to the effects of the experimental manipulations upon the number of probe selections required for solution. When subjects were allowed only one reading of the statement of the problem situation, a greater number of probes were selected when the statement was grammatically and syntactically complex than when the statement was expressed in simple and straightforward sentences. When three readings of the problem situation were allowed, however, no differences in the number of probe selections as a function of com-

plexity were observed.

Kintsch and Monk (1972) obtained similar results with a solution accuracy measure of performance in an inferential "problem-solving" task. These researchers concluded from their study that the organization and storage of information in memory is independent of the syntactic and grammatical complexity of the input materials, provided sufficient time for processing of the materials is allowed. Furthermore, these researchers suggested that since the simple and complex versions of each experimental paragraph had in common only semantic meaning, then subjects must have stored in memory representations of this invariant semantic meaning in the paragraphs. This interpretation was not to imply that each subject's cognitive representation of the problem materials was identical, but simply that what was stored in memory by a subject was the semantic meaning which was shared by each version of a paragraph.

While the results of the present study are consistent with those obtained by Kintsch and Monk, the present findings seem to lend themselves better to an alternative interpretation. The availability of a semantic context did not influence problem-solving efficiency in Experiment II. Subjects (specifically those in the no context groups) were apparently able to solve the problem by organizing and remembering only the relevant elements of the problem situation (i.e., the object groupings) without relating this information to an existing cognitive structure through the use of a semantic context. This finding suggests that subjects were not processing the input materials at a deep, context-dependent level, a condition which Tulving (1972) has

suggested is necessary for the storage of semantic content (p. 389). If this is the case, then the significant paragraph complexity by reading time interaction in Experiment II is likely not attributable to the storage of the invariant semantic contents of the simple and complex problem situations; rather, it appears to be dependent upon the degree of organization of the relevant problem elements which was achieved by the subjects. Greeno (1972) and his associates (Egan & Greeno, 1973; Mayer & Greeno, 1972) contend that such an organization need not be based upon the semantic meaning of the problem situation; it may simply consist of an understanding of the interrrelationships of the problem elements themselves (i.e., internal connectedness). These researchers have found that this latter superficial level of connectedness is sufficient for the solution of problems which can be solved by means of a straightforward use of the information in the problem situation, but not for problems in which an interpretation of the problem information is required. As was mentioned earlier, by the time the experimental problem was presented in the present study, most subjects were likely aware of the requirements of the task, and therefore were able to solve the problem simply by organizing and remembering the object groupings themselves. Such an organization and storage of the specific problem elements resembles the internal connectedness discussed by Greeno and his co-workers, which suggests that an interpretational use of the problem situation was not required for problem solution in the present study; rather, an internal connectedness of the object groupings was sufficient for solution.

In the simple version of the problem situation, the grouping of

the objects was expressed in a logical and straightforward manner. Therefore, those subjects who were presented this simple version were able to achieve an internal connectedness of the relevant problem elements with only a single reading of the problem situation. However, when the complex version was presented, more than a single reading was required for an understanding of the interrelationships of the object groupings. In this latter case, three readings were apparently sufficient for the development of this superficial structuring of the problem elements, but when only one reading was allowed, subjects were able to achieve internal connectedness only in the process of studying and selecting interrogative probes. As a result, these latter subjects (i.e., in the complex paragraph-one reading condition) required more probe selections and more time in order to solve the problem than did the remaining subjects.

It is possible that not only the present results, but also those of Kintsch and Monk, may have been due to the development of an internal connectedness of the problem elements by those subjects who were provided sufficient reading time. However, in view of the many differences between the present study and that conducted by Kintsch and Monk (e.g., piecemeal presentation of the problem situation vs. allowing the subjects to see the entire paragraph at one time; allowing subjects, at most, three readings of the problem situation vs. an unlimited amount of reading time; problem solution through the use of information apart from that provided in the problem situation vs. an inferential task in which the only information provided is in the statement of the problem situation), a more moderate position has been

taken here; namely, that each interpretation is accurate for the type of experimental situation employed in the two studies.

The ANACOVA in which total time was treated as the variate and Efficiency Score as the covariate indicated significant main effects for paragraph complexity and reading time. These findings indicate that when the total time measure of problem-solving efficiency is considered apart from the time associated with the probe selections, subjects required more time for problem solution when a complex problem situation was presented than when a simple problem situation was provided; more time was also needed when a single reading was allowed than when three readings were permitted. These results suggest that due to the complications in the problem organization resulting from the syntactically complex statement of the problem situation or from limited reading time, subjects in these conditions needed more time to understand the basic organization of the problem elements than did the remaining subjects.

Several studies have demonstrated the importance of preparation in problem solving (e.g., Buri & Slaymaker, Note 1; Johnson, 1961; Johnson, Lincoln, & Hall, 1961). Supplementary analyses of the data from Experiment II in the present study confirm these reports. The proportion of the total time spent in preparation was found to be negatively correlated with total time and with the Efficiency Scores, accounting for 29% and 38% of the variance, respectively. As indicated by the nonsignificant correlation between the proportion of the total time spent in preparation and the total time residuals of the regression of total time on the Efficiency Scores, each of these highly signifi-

cant negative correlations is due to the inverse relationship of the proportions of the total time spent in preparation to the number of probe selections required for solution. As the proportion of the total time in preparation increased, the number of probe selections needed for solution decreased.

Johnson et al. (1961) have offered a description of problem-solving behavior during preparation which may aid in the interpretation of these findings. They found that subjects spent much of their time during the preparatory period organizing a prospective solution strategy. Once that strategy was sufficiently organized by a subject, he proceeded to search for a behavior which would match his selected strategy and result in problem solution. In the present study, those subjects who were provided sufficient time to process the input materials were able to organize the information in the problem situation well enough that they could construct a solution strategy (or a partial solution strategy) during the preparatory period. The subsequent attempts by these subjects to implement the selected strategies in the solution of the problem generally met with success, as indicated by the overall lower Efficiency Scores for these subjects. When insufficient processing time was allowed, however, subjects did not have the problem elements organized well enough prior to the preparatory period that they were able to construct a prospective strategy during that time. As a result, many of these subjects made probe selections prior to formulating a strategy, apparently in an effort to obtain information which would enable them to organize the problem materials and subsequently solve the problem. The success of such an

approach in which a problem solution is attempted prior to the formulation of a tentative strategy is evidenced by the relatively greater number of probe selections required by these subjects for problem solution.

A significant reading time by context interaction was obtained in the ANACOVA in which the proportion of the total time spent in preparation was treated as the variate and total time and Efficiency Scores were treated as covariates. This finding indicates that when the effects of total time and Efficiency Scores are eliminated from the analyses, a greater proportion of the total time was spent in preparation when the context was provided after three readings of the problem situation than in any other condition. Apparently, while reading the statement of the problem situation, subjects attempted to organize the problem elements. This basic organization was developed and subsequently employed in the solution of the problem, provided information presented later did not disrupt it. When the context was presented prior to the statement of the problem situation or when the context was not provided, no new information was presented which would require the subjects to reorganize the problem elements. When the context was presented after the reading of the problem situation, however, subjects who had been able to construct a sufficient organization of the problem elements while reading the problem situation found that what they had organized could be better understood within the context of washing clothes. These subjects (i.e., allowed three readings) then took time prior to any probe selections to structure the problem elements consistent with the given context. Those sub-

jects who were only allowed a single reading of the problem situation, however, apparently were not able to construct an organization of the problem elements during the reading time which was strong enough that subsequent information would have a disruptive effect upon it. This is consistent with the conclusion offered above that subjects who were provided only a single reading required more time subsequent to that reading in order to gain an understanding of the basic organization of the problem elements. Only after this basic organization was understood could subjects proceed to develop a deeper understanding of the interrelationships of the problem elements and to devise a workable solution strategy.

SUMMARY

Two experiments were conducted to replicate and extend the findings of previous research on the availability of contextual information in prose materials. The problem was introduced with a consideration of the nature of contextual availability and its effect upon memory, and the role of memory in problem solving was then discussed. Tentative support for the facilitative effects of contextual availability were obtained in Experiment I, but the contextual manipulations in Experiment II were found to have no effect upon problem-solving performance. It is suggested that this lack of clear-cut evidence for contextual facilitation is the result of a superficial level of processing of the problem materials, which resulted from experimental conditions which primed subjects as to the requirements of the task.

In Experiment II, total time to problem solution and the number of items of information needed for solution were affected by paragraph complexity when insufficient processing time was allowed. No such differences were obtained, however, when subjects were given sufficient reading time. The argument is advanced that contrary to the interpretations of similar results offered in previous studies, these findings are not the result of the storage of the semantic content of the input materials.

The importance of preparation in the problem-solving process was also observed. As the proportion of the total time spent in preparation increased, problem-solving performance improved. These findings indicate that the more time a subject spends formulating a solution

strategy prior to an attempt to actively solve the problem, the better will be his performance.

REFERENCE NOTES

1. Buri, J. R. & Slaymaker, F. L. Preparation in problem solving: The longer you look, the better you leap. Paper presented at the Forty-seventh Annual Meeting of the Midwestern Psychological Association, Chicago, 1975.

REFERENCES

Ausubel, D. P. Educational Psychology: A Cognitive View. New York: Holt, Rinehart, & Winston, 1968.

Barclay, J. R. The role of comprehension in remembering sentences. Cognitive Psychology, 1973, 4, 229-254.

Barclay, J. R. & Reid, M. Characteristics of memory representations of sentence sets describing linear arrays. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 133-137.

Bartlett, F. C. Thinking: An Experimental and Social Study. New York: Basic Books, 1958.

Berlyne, C. E. Structure and Direction in Thinking. New York: Wiley & Sons, 1965.

Bever, T. G., Lackner, J. R., & Kirk, R. The underlying structures of sentences are the primary units of immediate speech processing. Perception and Psychophysics, 1969, 5, 225-234.

Blumenthal, A. Prompted recall of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 203-206.

Blumenthal, A. Language and Psychology. New York: Wiley & Sons, 1970.

Blumenthal, A. & Boakes, R. Prompted recall of sentences: A further study. Journal of Verbal Learning and Verbal Behavior, 1976, 6, 674-675.

Bourne, L. E., Jr., Ekstrand, B. R., & Dominowski, R. L. The Psychology of Thinking. Englewood Cliffs, N. J.: Prentice-Hall, 1971.

Bransford, J. D., Barclay, J. R., & Franks, J. J. Sentence Memory: A constructive versus interpretive approach. Cognitive Psychology, 1972, 3, 193-209.

Bransford, J. D., & Franks, J. J. The abstraction of linguistic ideas. Cognitive Psychology, 1971, 2, 331-350.

Bransford, J. D., & Franks, J. J. The abstraction of linguistic ideas: A review. Cognition: International Journal of Cognitive Psychology, 1972, 1, 211-249.

Bransford, J. D. & Johnson, M. K. Contextual prerequisites for understanding: Some investigations of comprehension and recall. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 717-726.

Bransford, J. D. & Johnson, M. K. Considerations of some problems of comprehension. In W. G. Chase (Ed.), Visual Information Processing. New York: Academic Press, 1973, 383-438.

Bruner, J. S. Going beyond the information given. In Contemporary Approaches to Cognition. Cambridge: Harvard University Press, 1957, 41-69.

Chomsky, N. Syntactic Structures. London: Mouton & Company, 1957.

Chomsky, N. Aspects of the Theory of Syntax. Cambridge: M. I. T. Press, 1965.

Chomsky, N. Language and Mind. New York: Harcourt, Brace, & World, 1968.

Clark, H. H. & Chase, W. G. On the process of comparing sentences against pictures. Cognitive Psychology, 1972, 3, 472-517.

Cofer, C. N . Reasoning as an associative process: III. The role of verbal responses in problem solving. Journal of General Psychology, 1957, 57, 55-68.

Cofer, C. N. Constructive processes in memory. American Scientist, 1973, 61, 537-643.

Davis, G. A. Current status of research and theory in human problem solving. Psychological Bulletin, 1966, 66, 36-54.

Doll, T. J. & Lapinski, R. H. Context effects in speeded comprehension and recall of sentences. Psychonomic Society Bulletin, 1974, 3, 342-344.

Dooling, J. D. Some context effects in the speeded comprehension of sentences. Journal of Experimental Psychology, 1972, 93, 56-62.

Dooling, D. J. & Lachman, R. Effects of comprehension on retention of prose. Journal of Experimental Psychology, 1971, 88, 216-222.

Dooling, D. J. & Mullet, R. L. Locus of thematic effects in retention of prose. Journal of Experimental Psychology, 1973, 97, 404-406.

Duncan, C. P. Human problem solving. Psychological Bulletin, 1959, 56, 397-399.

Duncker, K. On problem solving. Psychological Monographs, 1945, 58 (5, Whole No. 270).

Fillenbaum, S. Memory for gist: Some relevant variables. Language and Speech, 1966, 9, 217-227.

Flagg, P. W., Potts, G. R., & Reynolds, A. G. Instructions and response strategies in recognition memory for sentences. Journal of Experimental Psychology: Human Learning and Memory, 1975, 1, 592-598.

Forgus, R. H. & Schwartz, R. J. Efficient retention and transfer as affected by learning method. The Journal of Psychology, 1957, 48, 135-139.

Franks, J. J. & Bransford, J. D. Abstraction of visual patterns. Journal of Experimental Psychology, 1971, 90, 65-74.

Franks, J. J. & Bransford, J. D. The acquisition of abstract ideas. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 311-315.

Gagné, R. M. Problem solving. In A. W. Melton (Ed.), Categories of Human Learning. New York: Academic Press, 1964, 293-317.

Gagné, R. M. & Brown, L. T. Some factors in the programming of conceptual learning. Journal of Experimental Psychology, 1961, 62, 313-321.

Gomulicki, B. R. Recall as an abstractive process. Acta Psychologica, 1956, 12, 77-94.

Gough, P. B. Grammatical transformations and speed of understanding. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 107-111.

Greeno, J. G. On the acquisition of a simple cognitive structure. In E. Tulving & W. Donaldson (Eds.), Organization of Memory. New York: Academic Press, 1972, 353-377.

Greeno, J. G. The structure of memory and the process of solving problems. In R. L. Solso (Ed.), Contemporary Issues in Cognitive Psychology. Washington, D. C.: V. H. Winston & Sons, 1973, 103-133.

Greeno, J. G. Processes of learning and comprehension. In L. W. Gregg (Ed.), Knowledge and Cognition. Potomac, Md.: Erlbaum Associates, 1974, 17-28.

Harris, R. J. Memory and comprehension of implications and inferences of complex sentences. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 626-637.

Haslerud, G. M. & Meyers, S. The transfer value of given and individually derived principles. Journal of Educational Psychology, 1958, 49, 293-298.

Haviland, S. E. & Clark, H. H. What's new? Acquiring new information as a process in comprehension. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 512-521.

Hayes, J. R. Problem topology and the solution process. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 371-379.

Hilgard, E. R., Edgren, R. D., & Irvine, R. P. Errors in transfer following learning with understanding: Further studies with Katona's card-trick experiments. Journal of Experimental Psychology, 1954, 47, 457-464.

Hilgard, E. R., Irvine, R. P., & Whipple, J. E. Rote memorization, understanding, and transfer: An extension of Katona's card-trick experiments. Journal of Experimental Psychology, 1953, 46, 288-292.

Huttenlocher, J. & Weiner, S. L. Comprehension of instructions in varying contexts. Cognitive Psychology, 1971, 2, 369-385.

Jarvella, R. J. Syntactic processing of connected speech. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 409-416.

Johnson, D. M., Lincoln, R. E., & Hall, E. R. Amount of material and time of preparation for solving problems. Journal of Psychology, 1961, 51, 457-471.

Johnson, M. K., Bransford, J. D., & Solomon, S. K. Memory for tacit implications of sentences. Journal of Experimental Psychology, 1973, 98, 203-205.

Johnson, M. K., Doll, T. J., Bransford, J. D., & Lapinsky, R. H. Context effects in sentence memory. Journal of Experimental Psychology, 1974, 103, 358-360.

Katona, G. Organizing and Memorizing. New York: Columbia Unversity Press, 1940.

Katz, J. J. & Postal, P. M. An Integrated Theory of Linguistic Descriptions. Cambridge: M. I. T. Press, 1964.

Katz, S. Role of instructions in abstraction of linguistic ideas. Journal of Experimental Psychology, 1973, 98, 79-84.

Katz, S., Atkeson, B., & Lee, J. The Bransford-Franks linear effect: Integration or Artifact? Memory and Cognition, 1974, 2, 709-713.

Kieras, D. E. & Greeno, J. G. Effects of meaningfulness on judgments of computability. Memory and Cognition, 1975, 3, 349-355.

King, D. R. W. & Greeno, J. G. Invariance of inference time when information was presented in different linguistic formats. Memory and Cognition, 1974, 2, 233-235.

Kintsch, W. Notes on the structure of semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of Memory. New York: Academic Press, 1972, 249-309.

Kintsch, W. & Monk, D. Storage of complex information in memory: Some implications of the speed with which inferences can be made. Journal of Experimental Psychology, 1972, 94, 25-32.

Kirk, R. E. Experimental Design: Procedures for the Behavioral Sciences. Belmont, Calif.: Brooks/Cole Publishing Co., 1968.

Koffka, K. Principles of Gestalt Psychology. New York: Harcourt-Brace, 1935.

Lachman, R. & Dooling, D. J. Connected discourse and random strings: Effects of number of inputs on recognition and recall. Journal of Experimental Psychology, 1968, 77, 517-522.

Maier, N. R. F. What makes a problem difficult? In N. R. F. Maier (Ed.), Problem Solving and Creativity in Individuals and Groups. Belmont, Calif.: Brooks/Cole, 1970, 179-189.

Maltzman, I. Thinking: From a behavioristic point of view. Psychological Review, 1955, 62, 275-286.

Mayer, R. E. & Greeno, J. G. Effects of meaningfulness and organization on problem solving and computability judgments. Memory and Cognition, 1975, 3, 356-362.

Mehler, J. Some effects of grammatical transformations on the recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 346-351.

Meyers, L. S. & Boldrick, D. Memory for meaningful connected discourse. Journal of Experimental Psychology: Human Learning and Memory, 1975, 1, 584-591.

Miller, G. A. Some psychological studies of grammar. American Psychologist, 1962, 17, 748-762.

Mistler-Lachman, J. Levels of comprehension in processing of normal and ambiguous sentences. Journal of Verbal Learning and Verbal Behavior, 1972, 5, 614-623.

Neimark, E. D. & Santa, J. L. Thinking and concept attainment. Annual Review of Psychology, 1975, 26, 173-205.

Neisser, U. Cognitive Psychology. Englewood Cliffs, N. J.: Prentice-Hall, 1967.

Norman, D. A. Memory, knowledge, and the answering of questions. In R. L. Solso (Ed.), Contemporary Issues in Cognitive Psychology. Washington, D. C.: V. H. Winston & Sons, 1973, 135-165.

Olson, D. R. Language and thought: Aspects of a cognitive theory of semantics. Psychological Review, 1970, 77, 237-273.

Paige, J. M. & Simon, H. A. Cognitive processes in solving algebra word problems. In B. Kleinmutz (Ed.), Problem Solving: Research, Method, and Theory. New York: Wiley & Sons, 1966, 51-119.

Perfetti, C. R. Lexical density and phrase structure depth as variables in sentence retention. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 719-724.

Philipchalk, R. P. Thematicity, abstractness, and the long-term recall of connected discourse. Psychonomic Science, 1972, 27, 361-362.

Piaget, J. Science of Education and the Psychology of the Child. New York: Orion Press, 1970.

Pompi, K. F. & Lachman, R. Surrogate processes in the short-term retention of connected discourse. Journal of Experimental Psychology, 1967, 75, 143-150.

Posner, M. I. Cognition: An Introduction. Glenview, Ill.: Scott-Foresman, 1973.

Postal, P. M. Underlying and superficial linguistic structure. Harvard Educational Review, 1964, 34, 246-266.

Potts, G. R. Information processing strategies used in the encoding of linear orderings. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 727-740.

Raaheim, K. Problem solving and past experience. In P. S. Sears (Ed.), Intellectual Development. New York: Wiley & Sons, 1971, 379-387.

Sachs, J. S. Recognition memory for syntactic and semantic aspects of connected discourse. Perception and Psychophysics, 1967, 3, 437-442.

Savin, H. B. & Perchonock, E. Grammatical structure and the immediate recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 348-353.

Schwartz, D., Sparkman, J. P., & Deese, J. The process of understanding and judgments of comprehensibility. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 87-95.

Simon, H. A. & Lea, G. Problem solving and rule induction: A unified view. In L. W. Gregg (Ed.), Knowledge and Cognition. Potomac, Md.: Erlbaum Associates, 1974, 105-127.

Singer, M. A replication of Bransford and Franks' (1971) "The abstraction of linguistic ideas." Psychonomic Society Bulletin, 1973, 1, 416-418.

Singer, M. & Rosenberg, S. T. The role of grammatical relations in the abstraction of linguistic ideas. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 273-284.

Slobin, D. I. Grammatical transformations and sentence comprehension in childhood and adulthood. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 219-227.

Trabasso, T. Language and cognition. In W. G. Chase (Ed.), Visual Information Processing. New York: Academic Press, 1973, 439-459.

Trabasso, T., Rollins, H., & Shaughnessy, E. Storage and verification stages in processing concepts. Cognitive Psychology, 1971, 2, 239-289.

Tulving, E. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of Memory. New York: Academic Press, 1972, 381-403.

Wason, P. C. Response to affirmative and negative binary statements. British Journal of Psychology, 1961, 52, 133-142.

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1971.

Yuille, J. C. & Paivio, A. Abstractness and recall of connected discourse. Journal of Experimental Psychology, 1969, 82, 467-471.

APPENDIX I

Below are the instructions, as they were tape recorded and presented to each subject. The instructions were also typed on a separate sheet of paper, thus allowing the subjects to read them as they were being presented on the tape recorder.

"This is an experiment to see how well you can solve problems. You will be asked to solve several problems, one at a time.

"For each problem you will be given several sentences to read. These sentences describe a problem situation upon which the problem is based. Each of these sentences is typed on a seperate index card. You will be allowed to read and study each sentence for seven seconds. After you have read all of the sentences, the deck of index cards on which the sentences are typed will be taken from you.

"At that time you will be given a problem display board like the one that you see in front of you. At the top of this display board is typed the problem that I would like you to solve. This problem is based upon the sentences that were presented on the deck of index cards.

"On the display board, just below the statement of the problem is a series of narrow openings. Each of these openings has a question in it. Among the questions in these openings are several of the questions that a person might choose to ask in order to figure out the solution to the problem.

"Your task is to solve the problem which is presented at the top of the display board. The problem can be solved by obtaining answers the questions on the display board. The answer to a question can be

obtained by pulling the cardboard strip on which the question is typed approximately ½ inch to the right until the answer appears in the small square window next to the question.

"In solving the problem, you are free to choose which questions you want answered, obtaining the answers to those questions which you choose by pulling the cardboard strips on which those questions are typed approximately ½ inch to the right until the answers appear in the windows. Remember: You are free to choose any questions on the display board that you want answered, but work as carefully and as quickly as you can.

"To review the instructions briefly: First, I will give you a deck of index cards. There is one sentence typed on each card, and you will have seven seconds to read each sentence. The way that you will know when seven seconds is up is that I have beeps tape recorded at seven second intervals. When you hear the first beep, proceed to the first sentence in the deck of index cards and read it carefully. Continue studying that sentence until you hear another beep, at which time you should go to the next card in the deck and read the sentence on that card. Continue in this way until you have read each sentence in the deck of index cards.

"At that time, I will give you a problem display board. The problem that I would like you to solve is stated at the top of the display board, and it is based upon the information contained in the deck of index cards. The way that you are to solve the problem is by getting answers to some of the questions on the display board. You will find that you will need some of the answers, but not

necessarily all of them, in order to solve the problem. In the end, you will have to add, or subtract, certain numbers in order to figure out what the exact solution is. Once you figure out the solution, tell me what it is."

APPROVAL SHEET

The dissertation submitted by John R. Buri has been read and approved by the following Committee:

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The final copies have been examined by the director of the dissertation and the signature which appears below verifies that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is therefore accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May 19, 1976
Date

Frank Slaymaker
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