DOCUMENT RESUME

ED 121 114 FL 007 632

AUTHOR	Carpenter, Patricia A.; Just, Marcel Adam
TITLE	Linguistic Control of Information Processing. Final Report.
INSTITUTION	Carnegie-Mellon Univ., Pittsburgh, Pa. Dept. of Psychology.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
PUB DATE	30 Sep 75
GRANT	NIE-G-74-0016
NOTE	164p.; For related documents, see FL 007 636-637 and EJ 112 015
EDRS PRICE	MF-$0.83 HC-$8.69 Plus Postage
DESCRIPTORS	*Cognitive Processes; Language Skills; Language Tests; Linguistic Competence; Linguistic Theory; Memory; *Negative Forms (Language); *Psycholinguistics; *Reading Comprehension; Reading Tests; Sentence Structure; Syntax; *Testing; Verbal Tests
IDENTIFIERS	*Language Processing

ABSTRACT

This research explored the fundamental processes involved in comprehending linguistic material: the duration of the process, the sequence of processes, and the sources of errors. One project examined the comprehension of affirmative and negative sentences that are read and verified with respect to a picture. A model developed to account for the sequence and duration of operations in this task also accounted for the processing of negatives in various situations, such as negatives in instructions and in test items. Another project explored how the information structure of a sentence affects comprehension. Each sentence in a paragraph generally contains some information previously given, and some new information. This project demonstrated that readers treat the two kinds of information differently. This research led to an analysis of what makes good writing: it uses the linguistic devices that minimize comprehension difficulties. A final project explored the use of eye fixations to track the processes that occur during comprehension, examining how subjects fixate a sentence and picture during various comprehension tasks. It was shown that the sequence and duration of the eye fixations can be explained in terms of the mental processes that occur during comprehension. Other papers resulting from the original research are not included here. (Author/CLK)

FINAL REPORT

Linguistic control of information processing

National Institute of Education Project N. I. E. G-74-0016

Patricia A. Carpenter

and

Marcel Adam Just

Co-principal investigators

Psychology Department
'arnegie-Mellon University
Pittsburgh, Pa. 15213

September 30, 1975

The research reported herein was performed pursuant to a grant from the National Institute of Education, U. S. Department of Health, Education and Welfare. Points of view or opinions stated do not necessarily represent official National Institute of Education position or policy.

TABLE OF CONTENTS

Papers resulting from research supported in part by NIE Grant G-74-0016

1. Carpenter, P. A. and Just, M. A. Linguistic influences on picture scanning. In R. A. Monty & J. W. Senders (Eds.), Eye Movements and Psychological Processes: Hillsdale, N. J., Lawrence Erlbaum Associates, 1975, in press.

2. Carpenter, P. A. and Just, M. A. Sentence comprehension: A psycholinguistic processing model of verification. Psychological Review, 1975, 82, 45-73.

3. Just, M. A. and Carpenter, P. A. Verbal comprehension in instructional situations. In D. Klahr (Ed.), Cognition and Instruction. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1975, in press.

4. Just, M. A. and Carpenter, P. A. The semantics of locative information in pictures and mental images. British Journal of Psychology, 1975, in press.

5. Just, M. A. and Carpenter, P. A. Comparative studies of comprehension: An investigation of Chinese, Norwegian, and English. Memory and Cognition, 1975, 3, 465-473.

6. Carpenter, P. A. and Just, M. A. Integrative processes in comprehension. In D. LaBerge & J. Samuels (Eds.), Perception and Comprehension, Hillsdale, N. J.: Lawrence Erlbaum Associates, 1976, in press.

7. Just, M. A. and Carpenter, P. A. Eye fixations and cognitive processes. Under editorial review.

8. Christie, J. M. and Just, M. A. Remembering the location and content of sentences in a prose passage. Under editorial review.

9. Just, M. A. and Carpenter, P. A. The relation between comprehending and remembering some complex sentences. Memory and Cognition, in press.

Convention Papers Presented:

1. Just, M. A. Predicting sentence memory performance from a model of the comprehension process. Paper presented at the Psychonomic Society Meetings, November, 1974, Boston, Mass.

2. Carpenter, P. A. Eye fixations during sentence comprehension. Paper presented at the Fifteenth Annual Meeting of the Psychonomic Society, November, 1974, Boston, Mass.

3. The operations underlying mental rotation. Invited paper. Midwestern Psychological Association, May 1-3, 1975, Chicago, Illinois.

PREFACE

In our proposal dated 4/2/75 (and revised 5/20/75), we outlined two main areas of research on fundamental skills in comprehension. One was the processing of negative sentences in instructions and in tests of verbal comprehension. The other area was the role of linguistic information structure in processing sentences and instructions. Our research in these areas is discussed in four manuscripts that are currently in various stages of publication. These manuscripts comprise four chapters of this final report.

The first chapter, entitled "Verbal Comprehension in Instructional Situations", considers the role of negation in understanding and executing instructions. Negation was chosen because it is a very pervasive linguistic structure. Moreover, negative sentences cause comprehension problems that reveal some of the fundamental limitations in verbal comprehension. This chapter presents a detailed model of the psychological processes involved in comprehending negative and affirmative sentences. The model accounts for the time people take to understand these sentences, the errors that they make, and the probability that they will later successfully remember the sentence. This chapter also discusses the role of comprehension skills in various testing situations. If a person cannot answer a test item or follow an instruction. it may be because the linguistic structure of the item taxes the reader's abilities. To exemplify this point, the paper analyzes several items from various tests and shows that a significant component in successful performance is understanding the wording of the items.

One test that is very often used to measure academic abilities or predict future academic success is the reading comprehension test. In this test a person is given a passage to read and then a number of questions about the passage. Our preliminary research on this test suggested that one important factor that determines performance is the ability to remember where the information is located in a passage. We investigated this skill and reported the results in Chapter 2, entitled "Memory for the Content and Location of Sentences in a Prose Passage." This represents the first steps in an analysis of the fundamental skills involved in successful performance on tests of reading comprehension.

A third chapter, entitled "Integrative Processes in Comprehension," examines the role of information structure on how sentences are read and remembered. This chapter examines a number of linguistic devices that can be used to facilitate a reader's comprehension. Moreover, it goes on to demonstrate that these devices are used by good writers. This analysis suggests that the rules for writing may be viewed from the vantage point of psycholinguistic processing; that is, good writing facilitates a reader's comprehension processes. All together, these first three chapters examine a number of fundamental skills that compose linguistic competence and explores their role in various comprehension tasks.

The fourth chapter, entitled "Linguistic Control of Picture Scanning," outlines an exciting methodology that we are developing to track very rapid mental processes. The preliminary data in this chapter and in an accompanying paper ("Eye Fixations and Cognitive Processes") suggest that a person's eye fixations are very sensitive to his underlying mental processes. In particular, a prior linguistic input can influence the way a subject scans a subsequent picture. The sequence and duration of the subject's eye fixations can be related to the mental processes involved in comprehending the linguistic input. We are currently developing this methodology to examine reading processes. By controlling the nature of the linguistic material that is being read, we are able to determine from eye movements, the precise problems that a reader has in comprehension.

A final chapter provides a summary of the other projects that were partially supported by Grant NIE-G-74-0016. These projects focus on various aspects of cognition and comprehension and provide further support for the conclusions reached in the preceding four chapters. Copies of each of these papers are included in an appendix.

Linguistic Control of Information Processing
Grant NIE-G-74-0016
Co-investigators: Patricia A. Carpenter
and
Marcel Adam Just

Educational Resources Information Center

Abstract

This research explored the fundamental processes involved in comprehending linguistic material, such as the duration of the process, the sequence of processes, and the sources of errors. One project examined the comprehension of affirmative and negative sentences that are read and verified with respect to a picture. For example, the sentence The dots aren't red would be verified with respect to a picture of all red dots or all black ones. Negative sentences took longer to process than corresponding affirmative sentences. A model was developed to account for the sequence and duration of operations in this task. Moreover, this model could also account for the processing of negatives in a number of other situations, such as negatives in instructions and in test items.

Another project explored how the information structure of a sentence affects comprehension. Each sentence in a pargraph generally contains some information that has been previously given (old information) and some new information. This project demonstrated that readers treat the two kinds of information differently. It was shown that several linguistic devices can cue the old-new distinction. Moreover, appropriate cues decrease the amount of time a person takes to read a paragraph and results in a more integrated memory structure in a subsequent memory task. This research lead to an analysis of what makes good writing. It was

argued that good writing uses the linguistic devices that minimize the comprehension difficulties of the reader.

A final project explored the use of eye fixations to track the processes that occur during comprehension. This research examined how subjects fixate a sentence and picture during various comprehension tasks. It was shown that the sequence and duration of the eye fixations can be explained in terms of the mental processes that occur during comprehension.

Linguistic Control of Information Processing
NIE Grant G-74-0016
Co investigators: Patricia A. Carpenter & Marcel Adam Just

Summary

Understanding written or spoken sentences is an important part of our everyday life; it influences how we read newspapers, books, technical reports and instruction manuals; it influences how we communicate with other people. Because of the pervasiveness and importance of the comprehension process, we have examined what mental events transpire when we understand sentences. This research may indicate ways to minimize the problems people have in understanding, and teach them to understand faster and more efficiently, and it may indicate how text should be written so as to optimize the reader's comprehension processes.

The current research asks specific questions about the mental events that occur during comprehension. One question is what information does a person extract from a sentence and how is that information internally symbolized in the reader's mind. Another question is what kinds of internal operations are performed when the listener mentally manipulates the information. For example, how is the information used when the reader wants to check if the sentence is true or not? The current research attempts to answer these questions by examining how long people take to process various kinds of sentences. By precisely measuring the duration of the comprehension process under various conditions, we have been able to infer exactly what processing goes on. One aim of this research is to be able to specify how a reader's comprehension skills could be improved. A second aim is to determine what kinds of linguistic structures are easier to understand than others. This may lead to a

guide for writing better prose in the many situations where efficient comprehension is important.

One part of this research has been concerned with how people process negative sentences. One reason to study negation is that it is a common linguistic structure; negative elements may appear explicitly as the _not_ in _The door isn't closed_, or implicitly in verbs like _forget_, _thoughtless_, _absent_, or in quantifiers like _few_, _scarcely any_, _none_, _seldom_, _never_, etc. A second reason to study negation is that it is common to all languages and it is one of the earliest semantic functions that children acquire. A third reason is that negatives are harder to comprehend than corresponding affirmatives. This research led to a detailed account of the mental events that occur when we process a negative sentence, specifying the durations of the component events.

To examine why negatives are harder to comprehend, we asked people to read and verify simple negative and affirmative sentences. For example, the person would be timed while he read a sentence like _The dots aren't red_ and looked at a picture of red or black dots. Several experiments indicated that part of the reason for the extra time is that it is harder to mentally represent a negative sentence, since the internal representation is more complex. However, there is another reason why negatives are harder to remember. Most information is coded in a positive manner. For example, we code what is present in a picture, not what is absent. Thus, a negative sentence does not easily match what we code about other events. The mismatch results in extra mental operations while we compare the representation of the sentence with the representation of the other information source, be it an accompanying picture or our general knowledge of the world.

This research suggests that if the use of a negative sentence is unavoidable, then its grammatical scope (i. e. the range of constituents to which it applies) should be minimized. Our research describes a theoretical basis for determining what kinds of sentences will be easier or harder to understand.

Another part of this project examined the linguistic devices that tell a reader how to integrate a sentence with previous sentences. One important fact about writing is that each sentence contains both old information that is related to previous sentences and new information that is related to previous sentences and new information. Comprehension is easier if the writer signals what information is old and what is new. For example, in conversation, a speaker generally puts vocal stress on elements that are new to the listener. This stress facilitates the listener's comprehension process. Similarly, in writing there are linguistic devices that can cue what information is old and what information is new.

Several experiments proved that this marking of old and new information influences comprehension. In a typical experiment, we asked a person to read a paragraph. The early sentences in the paragraph provided some information that was psychologically familiar or old by the time the reader reached later sentences. Then,we gave a sentence that used this old information and provided some new information. For example, an early sentence might have said <u>The little boy loved animals</u>. A later sentence might say <u>What he loved the most was his dog</u>. This second sentence marks as old the fact that the boy loved animals. This agrees with the reader's knowledge at that point. Readers could understand this sentence fairly quickly. By contrast, suppose the second sentence said The one who loved the dog was the little boy. This latter sentence seems awkward. It is "awkward" because the reader is given an incorrect signal about what is old information. This simple linguistic device has a large effect on how long it takes to read a paragraph. A number of other linguistic devices also serve to signal to the reader what is old and what is new. These distinctions help the reader relate each sentence to previous ones.

Good writers seem to be intuitively aware of these various linguistic devices and use them to write more comprehensibly. But not everyone is born with a writer's intuitions about how to write well. Thus, there is a need for some scientific study of what makes comprehensible prose. This research is an initial step in that direction. It indicates what kinds of sentences are difficult to understand, and why. This kind of knowledge may lead to a science of writing rules that would result in easily comprehensible prose. Such rules would help eliminate difficulties in areas where efficient communication is a primary goal.

A major objective of this research is to understand the fundamental cognitive processes that occur during understanding. This knowledge may point the way towards training people in comprehension skills. It is clear that some people have difficulty understanding written or spoken directions or reprots. Research on comprehension processes may allow us to diagnose the cause of these problems. Eventually, it is hoped that this kind of research will also indicate ways of remedying comprehension problems. Thus, research on fundamental skills may indicate how we can improve the skills of the reader as well as the writer.

A final part of the current research project has explored how people visually scan various kinds of written material. This is done by recording where their eye fixates while they read. For example, a person may be asked to read and solve a short, written problem. While reading, the person's eye generally fixates on various words as he progresses along. These fixations average about a quarter of a second. By comparing fixation patterns for easy and hard problems, we have been able to pinpoint the source of the difficulties that people are having. It appears that eye fixations will give a great deal of information about reading and comprehension problems. This research approach is now being explored in more detail.

CHAPTER I

Verbal Comprehension in Instructional Situations[1]

Marcel Adam Just

and

Patricia A. Carpenter

Psychology Department
Carnegie-Mellon University
Pittsburgh, Pa. 15213

Running head: Verbal Comprehension

Paper presented at the 10th Annual Carnegie Symposium on Cognition
Vail, Colorado, June 2-8, 1974.

To appear in Klahr, D. (Ed.), Cognition and Instruction. Potomac, Maryland: Lawrence Erlbaum Associates, 1975.

Probably the main medium for the acquisition of knowledge is verbal comprehension. The central importance of comprehension skill is recognized by our educational institutions and therefore, comprehension is often used as a criterion skill for measuring achievement and aptitude. In this paper, we will report on our investigation of one aspect of verbal comprehension, namely, the mental processes that underlie sentence comprehension. Our research takes the form of an information processing analysis, focusing on the information a person extracts from a sentence, how that information is represented internally, and what mental operations are applied to the representation. Our aim is to specify the parameters of the information processing system in simple comprehension tasks. We will validate our theoretical proposals by accounting for response latencies in a task where people decide whether a sentence is true or false. Then, we will examine verbal comprehension in a number of other tasks, showing how the same fundamental processes are common to these various situations.

This paper consists of three sections. First, we will outline an information processing model that accounts for response latencies in verifying simple and embedded affirmative and negative sentences. The negative sentences contained the explicit negative, _not_. Second, we will show that the same model explains how people execute simple instructions that contain implicitly negative lexical items like _except_, _different_, and _forget_. Third, we will examine two tasks that occur in educational tests of verbal comprehension, namely, sentence completion and reading comprehension, showing how performance in these tasks can be analyzed within the same theoretical framework.

AN INFORMATION PROCESSING MODEL OF SENTENCE VERIFICATION

The internal representation. Understanding a sentence involves internally representing the information that the sentence contains. It is likely that the format of the internal representation is propositional, a relational structure consisting of a predicate and one or more arguments. We will use the conventional notation, (PREDICATE, ARGUMENT), to denote a proposition. So part of the representation of a simple declarative sentence like The dots are red would be (RED, DOTS), meaning redness is predicated of the dots. Predications can be affirmed or negated. So, the entire representation of this affirmative sentence would be (AFF, (RED, DOTS)). A negative sentence like The dots aren't red would be represented as (NEG, (RED, DOTS)). AFF and NEG are embedding markers that denote the affirmative or negative polarity of the predication. This form of representation allows us to combine simple propositions to represent more complex sentences. For example, It is fortunate that the dots are red might be represented as (FORTUNATE, P), where P is the simple proposition (AFF, (RED, DOTS)).

The internal representation of a sentence is not necessarily linguistic in nature. The verbal symbols in these representations, e.g., DOTS, are used to denote more abstract entities. In fact, research on sentence-picture verification suggests that there may be a level of representation that is neither linguistic nor pictorial in nature but can represent information from either domain (Chase & Clark, 1972; Clark & Chase, 1972). For example, a picture of red dots may be represented (RED, DOTS). We assume that pictures are generally represented affirmatively, but by convention, we have deleted the affirmative polarity marker. The presence or absence of this marker in the picture representation has no consequence for any of our proposals, so long as it is assumed that the absence of a marker denotes affirmative polarity.

The detailed form of the representation of various kinds of sentences has not yet been empirically verified. For example, the research on the linguistic factors that determine the psychological predicate-argument structure has only begun (cf. Halliday, 1967; Hornby, 1972). Moreover, there are cases where various representations are formally equivalent and the selection of one particular form is really arbitrary. Nevertheless, this conventional notation is sufficient for the current model and promises to be flexible enough to accommodate a variety of linguistic structures (cf. Kintsch, 1972).

The same sentence may be represented differently in different situations. This follows from the assumption that the representation contains the information that a person extracts from a sentence. What information is extracted depends on the preceding sentences, the situation in which the sentence is embedded, and the listener's previous knowledge. In other words, context plays a role in how a sentence is represented, suggesting an important distinction between the psychological notion of an internal representation and the traditional linguistic notion of deep structure.

The task. We have recently proposed a model to account for the mental processes underlying the verification of affirmative and negative sentences (Carpenter & Just, 1974). The situation that originally gave rise to the model is a simple task in which a person must decide whether a sentence is true or false of a picture. For example, Just and Carpenter (1971) presented a sentence like The dots are red or The dots aren't red, as well as a picture of red dots or a picture of black dots. Thus, the sentence could be affirmative or negative, and true or false. A person was simply shown the picture, and then timed as he read the sentence and decided whether it was true or false. The results of this study showed that it took longer to verify negative sentences than affirmative sentences by a certain amount of time, called negation time. In this particular study, the negation time was a little more than two fifths of a second. The study also showed that affirmative sentences were verified faster when they were true than when they were false, while negative sentences were verified faster when they were false. The difference in verification latency between the true and false sentence was opposite in sign but equal in magnitude for affirmative and negative sentences. This time, called falsification time, was a little more than one fifth of a second in this study. These two results, the latency advantage of affirmative sentences, as well as the interaction between affirmative-negative and true-false, were also found in a number of previous studies (Wason & Jones, 1963; McMahon, 1963; Gough, 1965, 1966; Trabasso, Rollins, & Shaughnessy, 1971; Chase & Clark, 1972; Clark & Chase, 1972).

The mental operations. In this section we will outline a model that accurately predicts the verification latencies for these simple affirmative and negative sentences. We will show that it also accounts for the verification of embedded sentences. Moreover, the main tenets of the model will serve as a touchstone for our examination of comprehension processes in instructional situations.

The main focus of the model is on the operations that compare the sentence and picture representations. The model postulates that the corresponding constituents from the two representations are retrieved and compared, pair by pair. Moreover, the number of these retrieve and compare operations is assumed to be the primary determinant of the pattern of verification latencies. Figure 1 shows the proposed process in flow-chart form. The representations' propositional structure and embeddings provide an ordering relation on the constituents. This ordering determines the sequence in which constituents are compared. Inner propositions are compared before polarity markers. An AFF marker in a sentence representation is assumed to match the absence of a marker in the picture representation, since pictures are generally encoded affirmatively. The "find and compare" process is a serial, iterative operation that can be applied to repre-

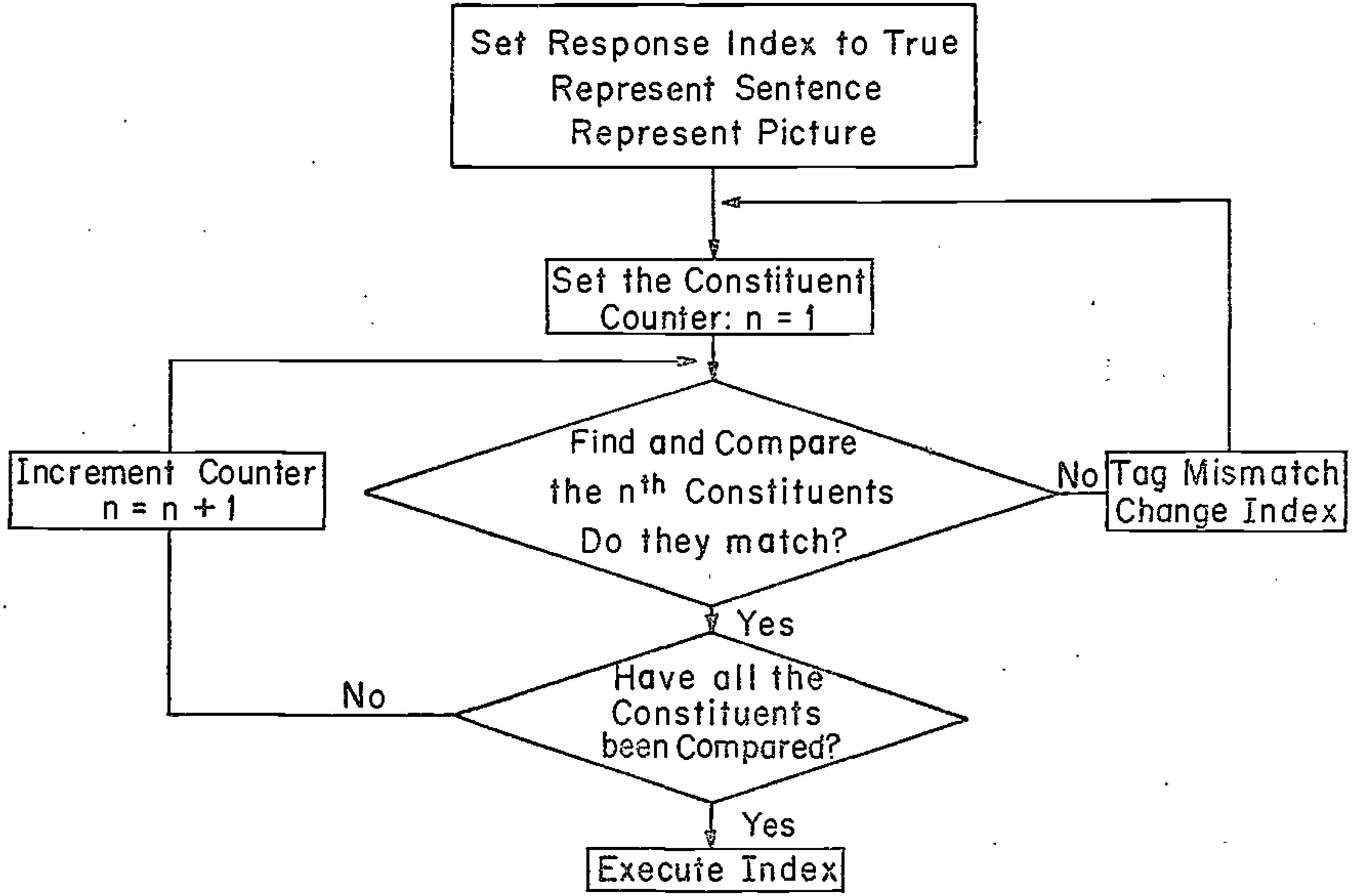


Figure 1

A flow-diagram of the constituent comparison model.

sentations with multiple embeddings. This iterative operation will allow the model to be generalized without additional assumptions.

Insert Figure 1 about here

A central assumption is that whenever two corresponding constituents from the sentence and picture representations mismatch, then the entire comparison process is re-initiated. To prevent the process from looping forever on mismatching constituents, we assume that the first time a mismatch is discovered, the two constituents involved are tagged, so that on subsequent recomparisons the two will be treated as a match.

Since mismatches cause the comparison process to be re-initiated, the total number of comparison operations, and consequently the total latency, increases with the number of mismatches. Moreover, a mismatch that occurs later in the comparison process results in more recomparisons than a mismatch on earlier constituents. So the total latency is a function of both the number of mismatches and their locus in their respective representations.

A response index monitors the matches and mismatches between constituents. The index has two possible states, <u>true</u> and <u>false</u>. At the beginning of each trial, its initial state is <u>true</u>, but each mismatch causes it to change from its current state to its other state. The time spent in changing the response index (and for that matter, tagging mismatching constituents) is assumed to be negligeable relative to the time to perform the find and compare operation.

Insert Table 1 about here

When the model is applied to the proposed sentence and picture representations in the Just and Carpenter experiment, it can account for the latencies in the four conditions. In the simplest case, the true affirmative, there are no mismatches between the sentence and picture representations, as shown in Table I. The first comparison, between the inner propositions, results in a match. The second comparison, between polarity markers, also results in a match. (The <u>AFF</u>

Table I

Representations and predictions for the four information conditions[a]

	True Affirmative	False Affirmative
Sentence:	The dots are red.	The dots are red.
Picture:	Red dots	Black dots
Sentence Representation:	(AFF, (RED, DOTS))	(AFF, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	+ +	- index = false
	response = true	+ +
	k comparisons	response = false
		k + 1 comparisons

	False Negative	True Negative
Sentence:	The dots aren't red.	The dots aren't red.
Picture:	Red dots	Black dots
Sentence Representation:	(NEG, (RED, DOTS))	(NEG, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	- + index = false	- index = false
	+ +	- + index = true
	response = false	+ +
	k + 2 comparisons	response = true
		k + 3 comparisons

[a]Plus and minus signs denote matches and mismatches of the corresponding constituents. Each horizontal line of plus and minus signs indicates a re-initiation of the comparison process.

marker in the sentence representation is presumed to match the absence of any polarity marker in the picture representation). Thus after a total of two constituent comparisons, the truth index is still set to true, and this response is executed. The number of constituent comparisons in the true affirmative case serves as the base line for the other conditions, and will be referred to as k. Here, k equals 2.

Insert Table II about here

In the false affirmative condition, the inner propositions of the sentence and picture mismatch. The mismatch will re-initiate the comparison process, causing one extra comparison above the base number. Table II shows the consequences of this mismatch in detail. The mismatching constituents are tagged and the response index is set to false. After the re-initiation, the tagged inner constituents are compared, and they match. The next comparison, between the polarity markers, also results in a match. So, the response false is executed after a total of k + 1 constituent comparisons.

In the false negative condition, there will be a total of k + 2 comparisons, due to the mismatch on the second constituent, the polarity markers. This mismatch will cause the response false to be executed. For the true negative condition, both the first and the second constituents mismatch, so that the response true will be executed after a total of k + 3 constituent comparisons.

The model postulates that verification latencies should be a direct function of the number of constituent comparisons. The number of comparisons, and hence the latency, should increase linearly from true affirmative (k), to false affirmatives (k + 1), to false negatives (k + 2), to true negatives (k + 3).

The results of the experiment, as well as the best fitting straight line, are shown in Figure 2. The predictions of the model fit the data quite well. The model accounts for 98.0% of the variance among the four means. The slope is 215 msec per constituent comparison.

Insert Figure 2 about here

Table II

A trace of the operations in verifying a false affirmative

	Stimulus sentence:	The dots are red.
	Stimulus picture:	A set of black dots

	Operations	
	Initialize response index to <u>true</u>	
	Represent sentence:	(AFF, (RED, DOTS))
	Represent picture:	(BLACK, DOTS)
1.	Compare first constituents	-
	Tag sentence constituent	(AFF, (M))
	Tag picture constituent:	(M)
	Change index to <u>false</u>	
	Re-initialize comparison process	
2.	Compare first constituents	+
3.	Compare second constituents	+
	Respond with content of index:	<u>False</u>
	Number of comparisons	k + 1, where k = 2

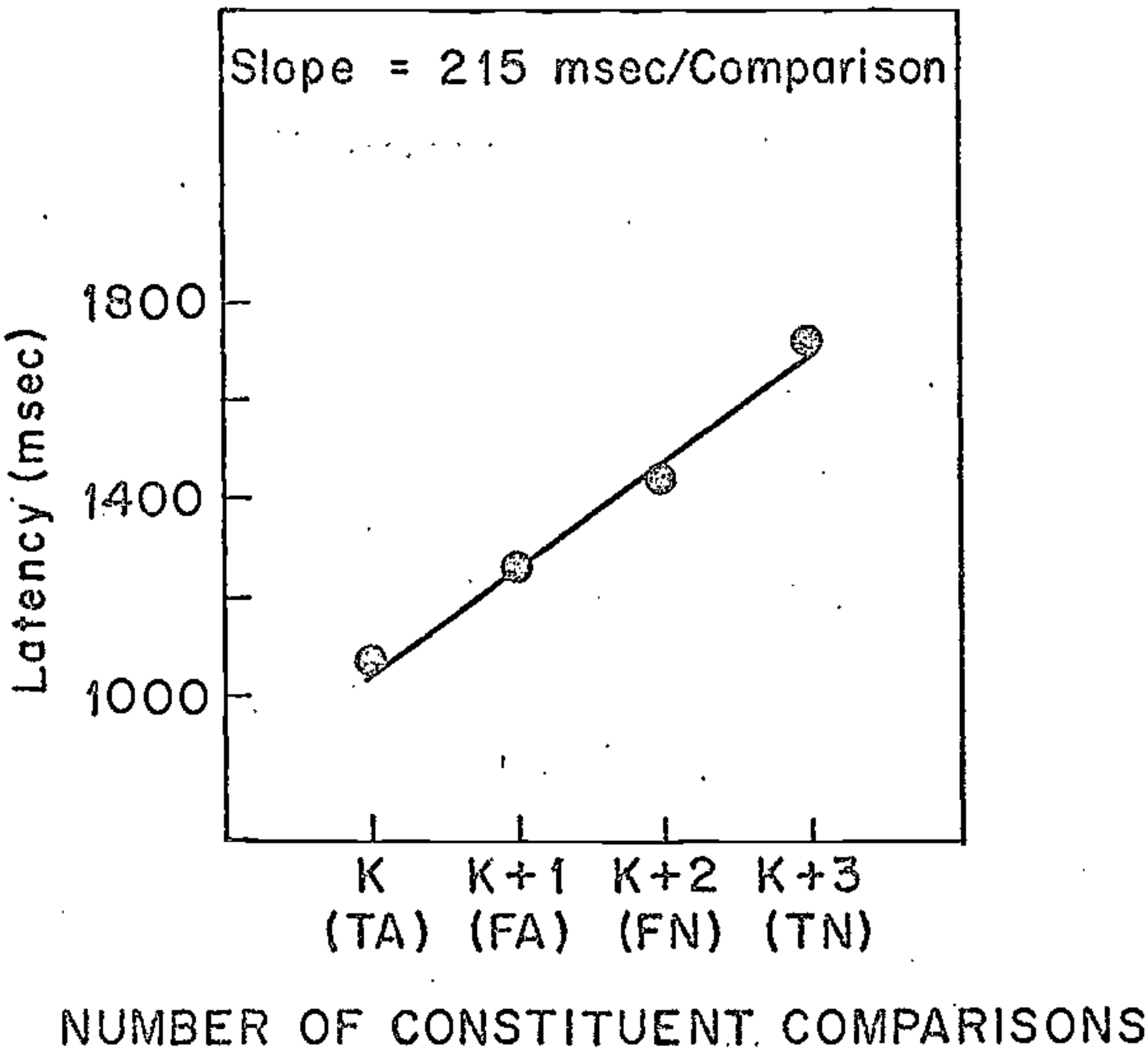


Figure 2

The fit of the constituent comparison model for the four information conditions (Data from Just & Carpenter, 1971, Exp. II)

Only one parameter, the time to find and compare a pair of constituents, is necessary to characterize the processing in these four conditions. Elsewhere (Carpenter & Just, 1974), we have tested the detailed predictions of the model and shown that it can also account for the latencies in many other similar experiments (i.e., Trabasso et al., Expt. IX, 1971; Clark & Chase, Expts. I, II, & III, 1972; Gough, 1965; Gough, Expt. II, 1966; McMahon, 1963). Thus, the current model provides a parsimonious explanation of performance in these tasks. Although parsimony is desirable, the model should be evaluated on the basis of its ability to offer a rigorous formulation that is both a plausible mental process and can incorporate a wide variety of empirical results. This ability will be demonstrated in each of the following sections. The nature of the propositional representation, particularly the embedding feature, should allow the model to be generalized to more complex sentences without additional modifications. This property of the model was tested by examining embedded affirmative and negative sentences.

A Test of the Model. To test the model's predictions, the scope of the negative was systematically varied. Other factors, like the sentence length and the picture, were kept constant. The scope of a negative is simply the range of constituents to which it applies (Klima, 1964; Jackendoff, 1969). The affirmative sentences used in the experiment included the superordinate clause It is true that ... (e.g., It is true that the dots are red) and could be negated in two ways. With one type of negation, the negative has a small scope, namely the inner predication: It is true that the dots aren't red. This will be called predicate negation. The second type of negation has a larger scope since the negative is in the superordinate clause where it applies to the entire inner proposition: It isn't true that the dots are red. This type of negation will be called denial. Denials should take longer to process than predicate negatives because the mismatch will occur on a constituent that is compared later.

The exact predictions can be derived by reviewing what the hypothesized representations for these sentence types are, and how they interact with the comparison process.

The representation of an affirmative sentence like It's true that the dots are red may be the same as for the simple sentence The dots are red, namely, (AFF, (RED, DOTS)). The rationale is that the embedding clause It's true... does not change the truth value and so it can be ignored. To demonstrate this point, consider a concatenation of this type of clause, e.g., It's true that it's true that it's true...the dots are red. The number of such embedding clauses is irrelevant to the truth value of the proposition. Similarly, the embedding affirmative proposition may be deleted from the representation of a predicate negative sentence like It's true that the dots aren't red, so that the representation would be (NEG, (RED, DOTS)). However, the representation of a denial like It isn't true that the dots are red, must include the negative embedding clause. Here the embedding clause does affect the truth value of the sentence. Thus, denial sentences might be represented like (NEG, (AFF, (RED, DOTS))). The pictures would be represented as simple propositions like (RED, DOTS) or (BLACK, DOTS). Table III shows examples of the representations in the six conditions.

The experiment was a verification task in which the person was timed while he read a sentence, looked at a picture, and then decided whether the sentence was true or false of the picture. There were 24 subjects.

Insert Table III about here

The predictions of the model can be derived by examining the flow chart model in Figure 1 and the representations in Table III. The predicted number of operations necessary to verify a true affirmative is k; a false affirmative is k + 1; a false predicate negative is k + 2; a true predicate negative is k + 3; a false denial is k + 4; and a true denial is k + 5. The verification latencies should increase linearly with the proposed number of operations. A

Table III

Representations and predictions for the six information conditions[a]

	True Affirmative	False Affirmative
Sentence:	It's true that the dots are red.	It's true that the dots are red.
Picture:	Red dots	Black dots
Sentence Representation:	(AFF, (RED, DOTS))	(AFF, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	+ +	- index = false
	response = true	+ +
	k comparisons	response = false
		k + 1 comparisons

	False Predicate Negative	True Predicate Negative
Sentence:	It's true that the dots aren't red.	It's true that the dots aren't red.
Picture:	Red dots	Black dots
Sentence Representation:	(NEG, (RED, DOTS))	(NEG, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	- + index = false	- index = false
	+ +	- + index = true
	response = false	+ +
	k + 2 comparison	response = true
		k + 3 comparisons

Table III continued

	False Denial	True Denial
Sentence:	It isn't true that the dots are red.	It isn't true that the dots are red.
Picture:	Red dots	Black dots
Sentence Representation:	(NEG, (AFF, (RED, DOTS)))	(NEG, (AFF, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	- + + index = false	- index = false
	+ + +	- + + index = true
	response = false	+ + +
	k + 4 comparisons	response = true
		k + 5 comparions

[a]Plus and minus signs denote matches and mismatches of the corresponding constituents. Each horizontal line of plus and minus signs indicates a re-initiation of the comparison process.

linear increase in latencies among these six conditions will constitute strong support for the constituent comparison model and the notion of a single underlying iterative operation.

The results showed that, as predicted, the mean latencies increased linearly with the number of hypothesized constituent comparisons. More precisely, latencies increased an average of 200 msec for each additional constituent comparison (Standard Error = 23 msec). Figure 3 shows this result, along with the best fitting straight line. The model accounts for 97.7% of the variance among the six means, $F(1,115) = 171.17$, $p < .01$. The residual 2.3% is not significant, $F(4,115) = 1.01$. The Root Mean Squared Deviation (RMSD) of 52 msec is small relative to the 200 msec parameter. This analysis confirms the major hypothesis that verification time increases linearly with the number of constituent comparisons.

Insert Figure 3 about here

The error rates for the six conditions were correlated with the latencies ($r = .98$), as is shown in Figure 3. This correlation indicates that the probability of error increases with the number of hypothesized operations.

The model is able to predict the processing time for these six conditions on the basis of a single parameter: the time to find and compare a pair of constituents. These results strongly support the hypothesis that a single iterative operation accounts for the processing of affirmative and negative sentences. The embedded representation, combined with the iterative comparison operation, allow the model to account for the two scopes of negation without additional assumptions.

A further control study showed that the representation and processing of the sentence is determined by its semantics, rather than by its surface structure. To show this, we compared the processing of sentences that had the same constituent structure but different surface structures. In this control study, the

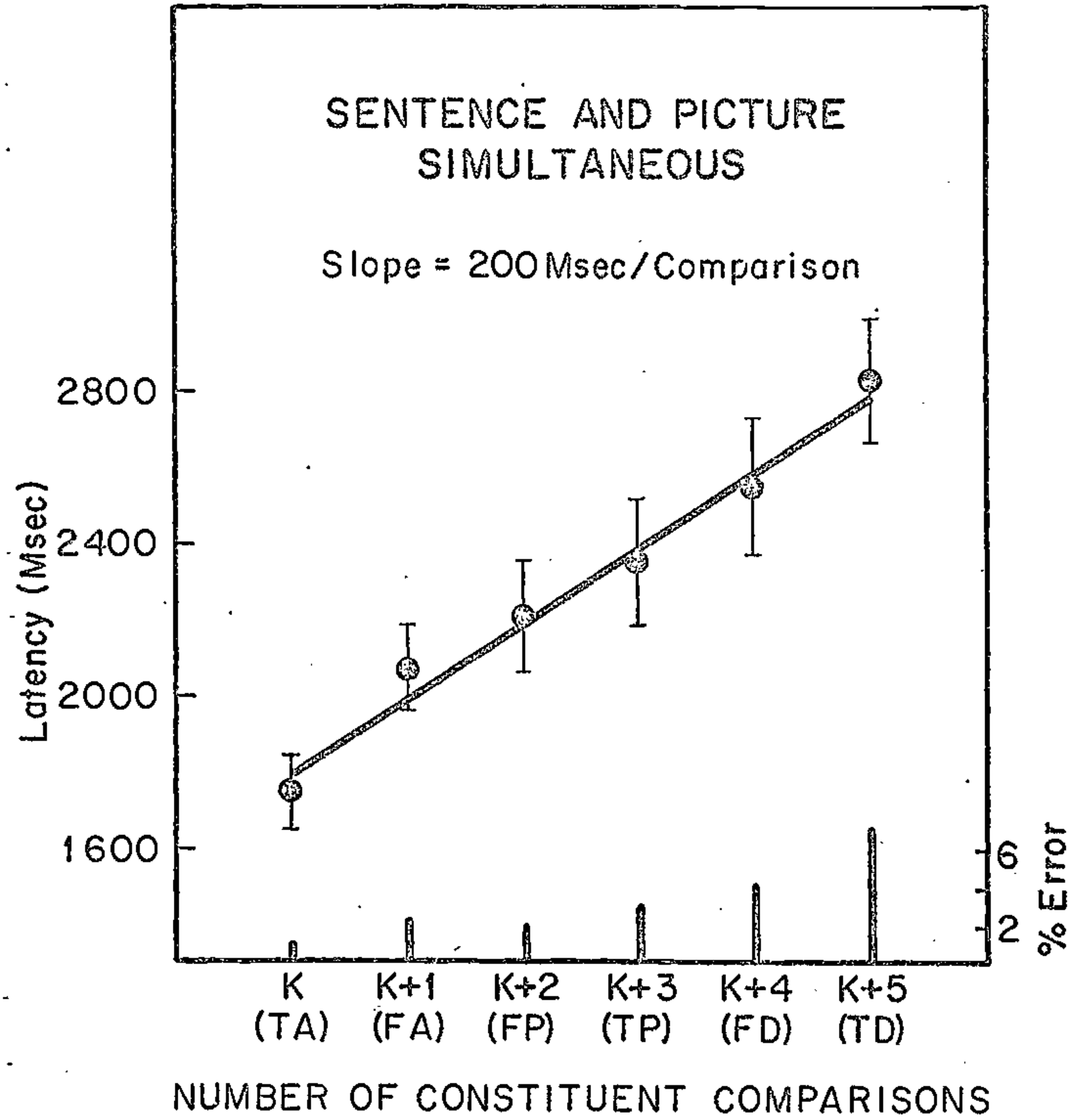


Figure 3

The fit of the constituent comparison model for the six information conditions.

inner propositions of the sentences were embedded in two ways: the same way as the previous experiment (e.g., It's true that the dots aren't red) and with the embedding clause at the end of the sentence (e.g., That the dots aren't red is true). Both of these kinds of sentences are postulated to have the same constituent structure. However, the position of the negative in the surface structure has been changed. If the results of the basic experiment can be replicated with the new sentences, then the results cannot be due to position of the negative morpheme in the surface structure. The new stimulus sentences were: Affirmative -- That the dots are red is true; Predicate negative -- That the dots aren't red is true; and Denial -- That the dots are red isn't true.

This control study showed the two types of surface structures were processed similarly. Both types of sentences showed a linear increase in latency as the number of comparisons increased. Regardless of whether the negative morpheme occurred near the beginning or end of the sentence, denials took about 500 msec longer to verify than predicate negatives. This result shows that the underlying constituent structure rather than order of negatives in the surface structure determines processing time, and constitutes further support for the proposed representations for the two kinds of negative sentences.

The mental processes described by this model are not specific to the sentence-verification paradigm, but occur in a large number of situations that involve verbal comprehension. These more general processes involve relating the information from a sentence to information from a second source, such as the listener's previous knowledge of the world. For example, in order to agree or disagree with a statement, it is necessary to compare the statement to a representation of one's own belief. In order to answer a Wh-question (e.g., Who painted the fence), the information provided in the question (e.g., that someone painted the fence) must be compared to previous knowledge before the interrogated constituent can be retrieved. In order to acquire new information through a verbal medium, the old information in the communication will serve as a basis to which the new information is added. The determination of which information is old can only be made if the sentence representation is compared to previous knowledge. And, in the next section of the paper, we will show that these comparison operations also occur when we follow simple instructions. Thus, the basic kinds of operations described by the model are part of a large class of comparison operations that occur very commonly when we comprehend linguistic material.

The mental operations described by the model are not specific to the processing of explicitly negative sentences but rather, they occur in the processing of a variety of semantic structures. Elsewhere, we have shown how the model accounts for semantic structures such as negative quantifiers like _few_, particular and universal quantifiers like _some_ and _all_ (Just, 1974), counterfactual clauses like _Mary would have left_... (Carpenter, 1973), and active and passive sentences like _The car hit the truck_ and _The truck was hit by the car_ (cf. Carpenter & Just, 1974). In the next section, we will show how the model also accounts for the processing of instructions that contain implicitly negative predicates.

COMPREHENDING IMPLICITLY NEGATIVE INSTRUCTIONS

A number of predicates like _forget_, _thoughtless_, _disagree_, and _absent_ are considered implicitly negative (cf. Klima, 1964; Just & Carpenter, 1971; Clark, in press). For example, we may define _forgot_ as _didn't remember_ or we may think of _absent_ as _not present_, and so on. By contrast, we don't generally think of _remembered_ as _didn't forget_. This suggests that there may be an asymmetry in how we internally represent pairs of lexical items like _remember_ and _forget_; an implicitly negative item like _forget_ may be internally represented as a negation of _remember_. This hypothesis can be tested by examining the data from a number of comprehension studies that have used such implicitly negative predicates. Two types of studies provide relevant data. The first type involves sentence verification tasks where the stimuli contained implicitly negative predicates. In the second type of study, the implicit negatives were in the instructions given to the subject. If predicates like forget are represented as negatives, then their processing should conform to the constituent comparison model.

Remember-Forget. The implicitly negative predicate forget to presents an interesting opportunity for examining the comprehension of negation. Not only is this predicate negative, but the proposition embedded in it is also negative. For example, the sentence John forgot to let the dog out directly implies that John didn't let the dog out (Karttunen, 1971). Thus one can study how people extract information from the implications of implicitly negative predicates, as Just and Clark did (1973). In that study, (Expt. II), subjects were presented with an affirmative sentence (John remembered to let the dog out) or an implicitly negative one (John forgot to let the dog out) and then were timed as they verified the probe sentence (e.g., The dog is in) as true or false of the implication of the parent sentence. The relevant information from a sentence like John forgot to let the dog out is that the dog isn't out. This may have been represented as (NEG, (OUT, DOG)). The information from a sentence with remembered to would be represented as (AFF, (OUT, DOG)). This sentence representation would be compared to a representation of the probe, like The dog is in, represented (AFF, (IN, DOG)). The model predicts that verification latencies should increase linearly from true--remembered, to false--remembered, to false--forgot, to true--forgot. The data conform very nicely to predictions of the model, which accounts for 94.6% of the variance among the four conditions, as shown in Table IV. This result shows that the implications of implicit negatives are processed similarly to explicitly negative sentences.

Insert Table IV about here

Table IV

Observed (and estimated) latencies for executing affirmative and implicitly negative instructions

				Number of Constituent Comparisons			
		Variance	Time	k	k + 1	k + 2	k + 3
	Example of implicitly	accounted for	per	Condition			
Reference	negative instruction	by model	comparison	TA	FA	FN	TN
remember-forget Just & Clark, 1973	If John forgot to let the dog in, then the dog is out, T or F?	95.0%	285 msec	2814 (2890)	3252 (3175)	3536 (3461)	3670 (3746)
present-absent Clark, in press	The star is absent, T or F?	94.8%	169 msec	1463 (1506)	1749 (1675)	1823 (1844)	2002 (2013)
same-different Seymour, 1969	Are the word and shape different, Y or N?	98.8%	82 msec	678 (667)	736 (749)	824 (831)	922 (913)
agree-conflict Trabasso, et al. 1971	Does the color name conflict with the color patch, Y or N?	99.4%	108 msec	828 (836)	959 (944)	1046 (1052)	1159 (1160)
synonymous-unrelated ...den & Clark	Are the two words unrelated, Y or N?	99.8%	145 msec	1117 (1121)	1266 (1266)	1423 (1410)	1547 (1555)

Present-Absent. A similar kind of verification task provides the evidence that indicates absent is internally represented as a negation of present. Sentences like The star is present or The star is absent were verified against pictures that either contained a star (*) or a plus (+), Clark (in press). If absent is internally represented as a negative, then a sentence like The star is absent might be represented as (NEG, (PRESENT, STAR)). This representation would be compared to the representation of the picture, either (PRESENT, STAR) or (PRESENT, PLUS), in this experiment. These representations can be used to generate the predictions of the model. The latencies should increase linearly from true--present, to false--present, to false--absent, to true--absent. As Table IV shows, the model accounts for 94.8% of the variance among the four means, with an estimated 169 msec per constituent comparison. Thus, the results support the hypothesis that in this task, absent is interpreted as an implicit negative. Moreover, the quantitative relations among the four latencies support the idea that there is a serial retrieval and comparison of constituents from the internal representations of the sentence and picture.

The next several experiments are tasks in which the instructions contained implicit negatives. We will show that the comparison process postulated by the model for sentence verification also explains how people understand and execute simple instructions.

Same-Different. One experiment that used negative instructions involved comparing a word (either the word circle or square) to a picture (of either a circle or a square) (Seymour, 1969). One group of subjects was given an affirmative instruction; they were asked to respond "yes" if the word and picture had the same meaning and to respond "no" otherwise. Another group of subjects was given a negative instruction: Respond "yes" if the word and picture are different, and "no" otherwise. The instruction involving the predicate different may have been represented with a negative: Respond "yes" if the picture is not the same as the word--(NEG, (IS,X)) where the symbol X takes the value denoted by the word.. For example, when the word was circle, it would be coded into the instruction as (NEG, (IS, CIRCLE)). Then, this representation would be compared to the picture representation. If the picture was a square, the comparison between the representation of the instruction and the representation of the picture, (IS, SQUARE), would result in a "yes" response. If the instruction were compared to a picture of a circle, the comparison would result in a "no" response. Each time an instruction with different is executed, the subject is essentially processing a negative construction. Therefore, the model predicts that latencies should increase linearly from "yes"--same, to "no"--same, to "no"--different, to "yes"--different. As Table IV shows, the model accounts for 98.8% of the variance among the four means, with a slope of 82 msec per constituent comparison. This supports the hypothesis that different is internally represented as an implicit negative. Moreover, the results show that the mental processes involved in executing instructions can be explained by the model for sentence verification.

Agree-Conflict. A very similar experiment by Trabasso et al. (Expt. X, 1971) can be analyzed to test whether the predicate conflict is internally represented as a negative. The task was to compare a word (either orange or green) to a picture that was colored either orange or green. One group of subjects was given an affirmative instruction: Judge whether or not the word and picture agree. Another group was given an implicitly negative instruction: Judge whether or not the word and picture conflict. The instruction involving conflict might be represented as (NEG, (IS, X)), where the symbol X would take the value of the color word presented during the trial. For example, suppose the word orange were presented; it would be coded into the instruction as (NEG, (IS, ORANGE)) and then compared to the picture. If the picture were colored green, the comparison between the representation of the instruction and the representation of the picture, (IS, GREEN), would result in a response of "yes." If the instruction were compared to an orange picture, it would result in a response of "no." These representations lead to the prediction that the latencies should increase linearly from "yes"--agree, to "no"--agree, to "no"--conflict, to "yes"--conflict. As Table IV shows, the model accounts for 99.4% of the variance among the four means, with an estimate of 109 msec per constituent comparison. This supports the hypothesis that the processes involved in following simple instructions with agree and conflict are the operations of representing, retrieving, and comparing constituents.

Synonymous--unrelated. The lexical item unrelated may also be represented as an implicit negative. To test this hypothesis, Hayden and Clark asked people to judge the semantic relation between two words that had the same meaning (e.g., large and big) or different meanings (e.g., large and tidy) (reported by Clark, in press). One group of subjects was given an affirmative instruction: Judge whether or not the two words are synonymous. Another group was given an implicitly negative instruction: Judge whether or not the two words are unrelated. The instruction with unrelated may have been represented like the implicit negatives different and conflict: (NEG, (MEANS, X)), where X takes on the value of one of the two words presented in a trial. For example, suppose the pair (large - tidy) were presented. The first word might be coded into the instruction, (NEG, (MEANS, LARGE)). The second word would be coded as (MEANS, TIDY) and then compared to the representation of the instruction. In this case, the response would be "yes". If the second word were big, the response would have been "no". The model predicts that latencies should increase linearly from "yes"--synonymous, to "no"--synonymous, to "no"--unrelated, to "yes"--unrelated. As Table IV shows, the model accounts for 99.8% of the variance among the means, with an estimate of 145 msec per constituent comparison. This supports the hypothesis that unrelated is represented and executed as a negative instruction. As in the cases of different and conflict, the negative item unrelated takes longer to execute and causes the "yes" response to take longer than the "no" response.

Except. In a very different kind of task, Jones (1966a, 1966b, 1968) examined how people execute instructions that contain the implicitly negative word except. In these tasks, people would read an affirmative instruction like "Cross out the numbers 1,3,4,6,7" or a negative instruction like "Cross out all the numbers except 2,5,8". Then they were given a sheet that was filled with the digits 1 to 8 in random order and timed while they performed the task. The two instructions require the same overt responses;but if except is a negative, the two instructions will cause very different mental operations. We hypothesized that the instruction with except is represented as: (NEG, (IS, 2 or 5 or 8)). Each digit encountered on the page would be represented (IS, X), where X takes the value of the digit. The digit will be crossed out if there are two mismatches between the two representations. This would happen if X took the value 7, for example. By contrast, the affirmative instruction would be represented (AFF,(IS, 1 or 3 or 4 or 6 or 7)). Each digit encountered on the page would be represented as (IS, X) so the digit would be crossed out if there were no mismatches. The negative instruction took a significant 13 sec longer to execute, and resulted in significantly more false positive errors (crossing out digits that weren't supposed to be crossed out).

In a second experiment, Jones equated the number of digits to be represented in an instruction. The positive instruction was "Cross out the digits 3,4,7,8." The negative instruction was to "Cross out all numbers except 1,2,5,6." Again, the negative instruction took much longer to execute (by 100 sec) and resulted in more false positive errors. Thus, executing a negative instruction, even in a very different kind of task, takes significantly longer than executing the equivalent affirmative one. This is consistent with the hypothesis that mismatches between the internal representation of an instruction and the representation of some second source of information, will lead to longer latencies.

The preceding analysis makes it clear that certain single words are internally represented with two components--an affirmative core as well as a negative component. While we cannot specify *a priori* whether or not a word is internally represented as a negative, our model does provide a valuable litmus test. If the verification latencies for a suspect word are shorter for false than for true, then the word is being represented and processed as a negative in that situation. Thus, the results cited above show that *forget*, *different*, *unrelated*, *conflict*, and *except* are represented as negatives. And the same kind of analysis can also exonerate suspect words. For example, *small* is not processed as a negation of *large*; it is represented as an affirmative (Just & Carpenter, 1971; Carpenter & Just, 1972). Thus, the theory provides a procedure to discriminate negative lexical items from affirmative items.

Other instructional examples. Comprehending an instruction can be a major source of difficulty in performing an everyday task. We sometimes encounter complex instructions where there is no conceivable purpose for their complexity. The following notice from the Internal Revenue Service provides an example (italics added).

ANY QUESTIONS ABOUT THIS NOTICE?

In the event we *failed* to give you credit for a Federal tax deposit or any other payment you made, please accept our apology and be guided by the following:

1. If the payment *not* credited was made within the last four weeks or so, we will credit it soon. You need *not* write us. Just subtract the payment we *haven't* included.

2. If the payment not credited was made more than four weeks ago, subtract it from the balance due...

3. If you have paid the entire balance due within the last four weeks, please disregard this notice.

Please send us an explanation if the balance is incorrect for any reasons other than payments we haven't credited.

EXPLANATION OF PENALTY OR INTEREST CHARGES

Your return was not filed and your tax was not paid by the due date. The combined penalty is 5 percent of the tax not timely paid for each month or part of a month the return was late, but not more than 25 percent.

This notice is not the result of an audit of your return. When we select a return for audit, we notify the taxpayer.

Presumably the IRS is not interested in testing our comprehension skills.

In other situations, the purpose of a complex instruction is precisely to assess comprehension skills, as illustrated by the following item (Personnel Test, Form D., E. F. Wonderlic).

Count each Z in this series that is followed by an F next to it if the F is not followed by an S next to it. Tell how many Z's you count. ZFZSEYZFSYFZFFSYSZFEZFSFZYFZFY

This is an extremely easy task if one comprehends the instruction, which could have been simplified as follows: Count the occurrences of the sequence (/Z/, /F/, /non-S/) in this series.

There are other situations where the purpose of complex instructions is not clear. The following example is taken from an aptitude test for prospective students of management science (Graduate Study in Management: A Guide for Prospective Students, Educational Testing Service):

Directions: Each of the data sufficiency problems below consists of a question and two statements, labeled (1) and (2), in which certain data are given. You have to decide whether the data given in the statements are sufficient for answering the questions. You are to blacken space

A. if statement (1) ALONE is sufficient, but statement (2) alone is not sufficient to answer the question asked;

B. if statement (2) ALONE is sufficient, but statement (1) alone is not sufficient to answer the question asked;

C. if BOTH statements (1) and (2) TOGETHER are sufficient to answer the question asked, but NEITHER statement ALONE is sufficient;

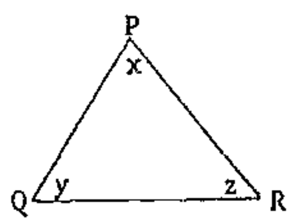
D. if EACH statement ALONE is sufficient to answer the question asked;

E. if statements (1) and (2) TOGETHER are NOT sufficient to answer the question asked, and additional data specific to the problem are needed.

Example: In Δ PQR, what is the value of x?

(1) $PQ = PR$

(2) $y = 40$



Answer: C

This kind of instruction seems to be testing both the ability to comprehend instructions, as well as knowledge of geometry and logic. Incorrect answers could be caused by any of these three sources. The relative contribution of comprehension difficulties can be assessed by rewriting these instructions in a simplified format.

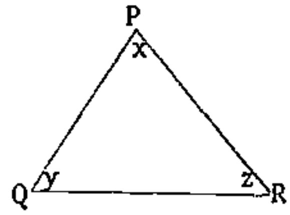
Revised Directions: Answer YES or NO to each of the following questions.

In Δ PQR, can you determine the value of x if all you know is that:

(1) PQ = PR? (Answer is NO)

(2) y = 40? (Answer is NO)

(3) PQ = PR and y = 40? (Answer is YES)



These examples illustrate how successful performance in a test may depend on comprehension skills in decoding the instruction, as well as the content skills that the test ostensibly taps. Thus, both components may enter into the test scores that can often predict future academic performance. It may turn out that the predictive ability of the test is partially due to the comprehension skills it taps, rather than the content skills. If the test is being used only for actuarial purposes, the relative loadings of the two factors are irrelevant. However, if the testing is for diagnostic purposes, then it is necessary to access the relative contribution of comprehension skills before remedial action can be taken. This may prove to be a fruitful approach to test construction.

In many situations, the primary purpose of an instruction is to inform, to help people perform correctly and efficiently. For example, instructions on income-tax forms, or in repair manuals should be constructed to minimize comprehension difficulties. A theory of sentence comprehension, such as we have outlined, suggests the kinds of problems that may arise in representing and executing various kinds of instructions. The theoretical approach also suggests ways of making everyday instructions easier to comprehend.

EDUCATIONAL TESTS OF VERBAL COMPREHENSION

Sentence completion tasks. Another domain in which we can apply our information processing analysis is the sentence-completion task, which often appears in tests of academic achievement or ability. This task involves choosing one of several alternatives that "best" completes a sentence frame. Consider the following example:

Beauty is only skin-deep, but ____ goes all the way to the bone.

a. disease b. blood c. ugliness d. fright

e. liniment (Answer: c)

Although performance in this task depends to some extent upon an adequate vocabulary, much of the processing can be explained in terms of the processes described by the comprehension model.

Many of the items in a sentence completion test have structures that are basically like the example above. These items consist of two parallel clauses of the same syntactic type, although there may be a negative lurking in one of them. The missing item is a constituent of one of the clauses. The connective between the two clauses is either affirmative (e.g., and) or negative (e.g., but). The polarity of the connective, as well as the presence of a negative in one of the clauses, determines whether the missing item should be an antonym or synonym of the corresponding constituent in other clause. In the example above, the negative connective but is a cue that the answer is an antonym of beauty.

A number of examples will give the flavor of the kinds of sentence completion items that involve negative connectives, like yet, but, unlike, whereas, and although (taken from a booklet, Preparation for college board examinations by Henry Regnery Co.).

Unlike his cousin, the artist, who was colorful, whimsical, and erratic, the teacher was prosaic, _____, and consistent.

a. infallible   b. commonplace   c. objective
d. disorganized   e. subtle

Though he was romantic and sensual in his outlook, his life was one of ______.

a. profligacy   b. naivete   c. austerity   d. virtuousity
e. maturity

These conditions are not ______ the nature of women but have grown up in spite of it.

a. intrinsic to   b. paramount in   c. compelling in
d. immutable in   e. extrinsic in

Early in the 19th century, in the South, it had become the fashion to raise only one stable crop, whereas in the North the crops were ________.

a. diversified   b. unstable   c. fallow   d. uniform
e. wild

In this game he was an amateur, not an expert, and thus, for the first time, became a(n) _____ instead of a man of action.

a. connoisseur   b. spectator   c. lawyer   d. pragmatist
e. authority

Linguistic analyses of the clausal conjunction but show that it involves incongruence between the two clauses. For example, but may be used if there is a lexical contrast between the two clauses, e.g., Mary likes school but John hates it. A second use of but involves a contrast between what is stated and what the speaker believes to be the usual connection between the two clauses, e.g., Bill is a politician but he's honest or Dick is a veterinarian but he doesn't like dogs (cf. Lakoff, 1971; Gleitman, 1969; Dik, 1968). Other connectives like instead, although, in spite of, however, and yet conjoin similar kinds of contrasting clauses.

In an experimental investigation of the completion task, Osgood and Richards (1973) asked subjects to complete sentences like X is beautiful --- dumb or X is old --- slow, with and or but. The two adjectives in the sentence either had the same or opposite affective polarity, which was determined a priori with the semantic differential. As the linguistic analysis would predict, incongruence between the two lexical items was a more favorable environment for but, whereas congruence was a more favorable environment for and.

The comparison model suggests what processes might underlie performance in this completion task. First, the sentence must be parsed into two parallel clauses. Then, the constituents of the clauses, including the coordinate conjunction and polarity markers, are checked serially for their polarity. The number of negatives determines whether it is a synonym or antonym of the provided constituent that is output as a response.

This model of processing can be tested with data collected during the sentence completion task. Hoosain (1973) measured latencies while people completed sentences like those in the Osgood and Richard's task, and he also varied the number of explicit negatives in the sentence. For example, a sentence could involve adjectives of similar affective polarity (e.g., Eve was mild---nice) or opposite affective polarity (e.g., Carl was troubled---happy), and could contain either no negatives at all, one negative (e.g., Eve was mild---not nice) or two negatives (e.g., Eve was not mild---not nice).

As might be expected, latencies increased as the number of negatives in the sentence increased from zero to one to two. Furthermore, latencies were shorter when the two adjectives were congruent in affective polarity. This difference was not affected by other factors, such as the number of extra operations caused by the presence of additional negatives. The results are completely consistent with a process that serially checks the constituents of the sentence. The presence of a negative results in a mismatch between the sentence representation and the affirmative frame with which it is compared. Such mismatches cause extra operations, whose durations are additive. Thus, the basic processes involved in this sentence-completion task are quite similar to the ones involved in comprehending and verifying sentences, although the control structures may be different for the two tasks. Processes in both tasks involve serially examining the constituents of representations, encountering mismatches, and consequently performing additional mental operations. This analysis has attempted to show that performance on a common item from a test of verbal skills can be analyzed in terms of underlying mental operations found in other comprehension tasks.

Potential applications: the reading comprehension test. In this section, we will try to outline the kinds of representations, retrieval and comparison operations in another task involving verbal comprehension, in this case, the reading comprehension test. This task is much more complex than the other ones that we have analyzed. The reading comprehension test involves reading a passage, usually 150-500 words long, and then answering 8 to 12 multiple-choice questions about the passage. The instructions are to first skim the passage for information when it is necessary. The time allotted to read the passage and answer all the questions is usually 5 to 15 minutes. We studied this task by having three subjects express their strategies and thoughts aloud while they performed several reading comprehension tests. Thus, this section represents a potential extension of the general approach, rather than an empirically confirmed model.

During the initial reading of the paragraph, the theme or central proposition of the passage is generally extracted and represented. Our subjects indicated they had represented the thematic information by their ability to answer the questions about the theme without looking back at the passage. In other studies, it has been shown that if subjects are kept from knowing the theme, both comprehension and memory for the passage suffers (Bransford & Johnson, 1973; Dooling & Lachman, 1971). Also, when recognition memory for individual sentences in a passage is tested, there is a much higher false-alarm rate for distractor sentences that contain the theme (Singer & Rosenberg, 1973). These results indicate that the thematic information plays a central role in the representation of the passage.

The initial representation of the passage also contains information about higher-order relations that exist between the thematic proposition and subsidiary propositions. These are relations such as causality and temporal order of events, which are sometimes cued by words like <u>because</u>, <u>consequently</u>, <u>after</u>, <u>before</u>, and so on. The representation of individual propositions linked by higher-order relations can be accommodated by a number of representational schemes (cf. Schank, 1973; Rumelhart, Lindsay & Norman, 1972; Kintsch, 1972; Crothers, 1972). Subjects often stored the occurrence of such higher-order relations without storing the content of the subsidiary proposition. For example, after the initial reading, a subject may have remembered that the consequences of a certain event were listed, but could not recall the specific instances.

The third kind of information extracted during the initial reading is a representation of the information development in the passage. Subjects seemed to store information that could act as a pointer to a particular part of the passage when a question required specific information. In a sense, the printed passage was used as an external memory, and the internal representation served as an indexing system for that external memory. Our subjects often knew where to look in the passage for specific information. For example, if a question alluded to a specific fact, the subject would say "I remember something about that just before the end" or "...that appeared in the middle." Then, he would proceed to search through the appropriate part of the passage. Of course, some of these strategies are probably due to the task conditions, which emphasize speed, but permit subjects to look back. So, after the initial reading, our subjects had a record of the location of certain information in the passage, as well as the main theme and a list of some relations between the theme and subsidiary propositions.

Our approach to the reading comprehension test is to focus on representing, indexing, retrieving, and comparing information. The emphasis on information processing activities has been at the expense of the obvious factor of vocabulary, previous knowledge of the words in the passage. Experimental evidence suggests that our de-emphasis of vocabulary is justified. Tuinman and Brady (1973) showed that thorough pretraining on vocabulary items from the reading passage did not raise the comprehension scores of children in grades four to six. While some minimal knowledge of the vocabulary is clearly a necessary condition for successful performance, it is not sufficient to improve performance beyond a given level. This study suggests that the important skill in reading comprehension is the ability to represent and manipulate the information presented in the passage and questions.

The advantage of analyzing the reading comprehension task in terms of information processing theory is that it defines the relevant empirical questions to be answered. One process to be explored is the mechanism that abstracts the theme. For example, it is possible that the thematic proposition is the one that occurs most frequently in the passage, as suggested by the simulation model of Rosenberg (1974). Another issue to be explored is the precise representation of the indexing system that records where facts were mentioned in the paragraph. And, how do particular questions tap into this index? This analysis provides an outline of how a complex task, like the reading comprehension test can be approached in terms of the basic components of the comprehension process--the representation, retrieval and comparison of information.

CONCLUSIONS

What makes a sentence hard to process? The comprehension model makes the claim that a sentence is difficult to process when it doesn't match the representation of some second source of information. Thus, the critical variable that determines processing difficulty is the matches or mismatches between two representations; the critical factor is not affirmation or negation, per se. According to the model, negatives are harder to process only when they mismatch with the affirmative representation of other information. For example, pictures are generally represented affirmatively, so sentences that refer to pictures are generally easier to process if they are affirmative. Similarly, the information stored in semantic memory is usually stored in some affirmative form, so the comprehension of sentence referring to semantic memory is usually easier if the sentence is affirmative. However, the implication of the model is clear--negatives are not necessarily harder to process than affirmatives; mismatches, rather than negation per se, determine the ease of comprehending linguistic information.

When negatives are easier. The model predicts that a negative sentence should be easier than an affirmative if the information from the other source were represented negatively. Then, the negative sentence would match the representation of the second source of information and the comparison would be faster. By contrast, the affirmative sentence would mismatch and processing would take longer. In fact, our analysis of an unusual reasoning task supports this prediction. Johnson-Laird and Tridgell (1972) presented subjects with a disjunctive premise ($p \vee q$) and a probe ($\sim q$), and asked the subjects to draw a conclusion (p). The premise contained two clauses like Either John is intelligent or John is rich. The probe sentence always had a different truth value than one of the two clauses in the premise, for example, John is not rich, so the conclusion was the remaining clause, i.e., John is intelligent.

The task required that the subject ask himself whether a clause in the premise conflicts with the probe. This self-instruction may have caused the same kind of internal representation that we postulated for instructions involving conflict, different, and disagree. The relevant clause in the premise may have been encoded into a negative instruction and then compared to the probe. For the example Either John is intelligent or John is rich, the second clause may have been coded into the instruction: (NEG, (X)), so that it resulted in the representation (NEG, (RICH, JOHN)). This was then compared to the probe, John is not rich, represented (NEG, (RICH, JOHN)). The model predicts that such a negative probe would be processed faster than an affirmative probe like John is poor, represented as (AFF, (POOR, JOHN)). As predicted, the response latency to negative probes was shorter (by 1.6 sec) than the latency for the affirmative probe. The model correctly makes the non-intuitive prediction that the negative probes are processed faster in this situation. This supports the argument that mismatches, rather than negatives per se, consume processing time. Thus, it is the relationship between two representations that determines the speed of comparison processes.

Processing instructions in an everyday situation. It was recently shown that in a highly realistic situation, people remember affirmative instruction much better than their negative counterparts. The situation was an airport, where eighty waiting airline passengers were asked to read or listen to a 200 word passage describing in-flight emergency procedures, based on actual airline protocol (File & Jew, 1973). The individual instructions were either affirmative (e.g., Extinguish cigarettes. Remove shoes.) or the corresponding negative set (e.g., Do not leave cigarettes lighted. Do not keep shoes on.). The results showed that the passengers recalled about 20% more information from affirmative instructions than from negative instructions. The better recall of affirmative instructions may have been the consequence of fewer mental operations during comprehension. Because the affirmatives are comprehended faster, subjects may have had more time to transfer information into long-term memory. The significance of this study is clear: laboratory-based theories of comprehension do apply to real situations involving critically important instructions.

We have examined several tasks that involve verbal comprehension in instructional settings. The focus has been on how the information in a sentence is represented and manipulated. We have proposed a general model to account for comprehension in a variety of situations, such as verifying or completing sentences and executing instructions. The kinds of tasks surveyed and the analysis have both practical and theoretical importance. On the practical side, this kind of analysis may help to localize the difficulties that an individual has in verbal comprehension. Moreover, this approach could lead to a set of rules for writing easily comprehensible instructions. Performance in these tasks also reflects the fundamental processes in verbal comprehension, helping to unravel the Gordian Not of comprehension.

References

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.

Carpenter, P. A. Extracting information from counterfactual clauses. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 512-521.

Carpenter, P. A., & Just, M. A. Semantic control of eye movements during picture scanning in a sentence-picture verification task. Perception and Psychophysics, 1972, 12, 61-64.

Carpenter, P. A., & Just, M. A. Sentence comprehension: An information processing model of verification. Psychological Review, 1974, in press.

Chase, W. G., & Clark, H. H. Mental operations in the comparison of sentences and pictures. In L. Gregg (Ed.), Cognition in Learning and Memory. New York: Wiley, 1972.

Clark, H. H. The chronometric study of meaning components. In J. Mehler (Ed.), Current Problems in Psycholinguistics. Paris: Centre National de la Recherche Scientifique, in press.

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

Crothers, E. J. Memory structure and the recall of discourse. In J. B. Carroll and R. O. Freedle (Eds.), Language Comprehension and the Acquisition of Knowledge. Washington, D. C.: Winston, 1972.

Dik, C. Coordination: Its Implication for the Theory of General Linguistics. Amsterdam: North-Holland, 1968.

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

File, S. E., & Jew, A. Syntax and the recall of instructions in a realistic situation. British Journal of Psychology, 1973, 64, 65-70.

Gleitman, L. Coordinating conjunction in English. In D. A. Reibel and S. A. Schane (Eds.), Modern Studies in English: Reading in Transformational Grammar. Englewood Cliffs, N. J.: Prentice-Hall, 1969.

Gough, P. B. Grammatical transformations and speed of understanding. Journal of Verbal Learning and Verbal Behavior, 1965, 5, 107-111.

Gough, P. B. The verification of sentences: The effects of delay of evidence and sentence length. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 492-496.

Halliday, M. A. K. Notes on transitivity and theme in English: II. Journal of Linguistics, 1967, 3, 199-244.

Hoosain, R. The processing of negation. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 618-626.

Hornby, P. A. The psychological subject and predicate. Cognitive Psychology, 1972, 3, 632-642.

Jackendoff, R. S. An interpretative theory of negation. Foundations of Language, 1969, 5, 218-241.

Johnson-Laird, P. N., & Tridgell, J. M. When negation is easier than affirmation. Quarterly Journal of Experimental Psychology, 1972, 24, 87-91.

Jones, S. The effect of a negative qualifier in an instruction. Journal of Verbal Learning and Verbal Behavior, 1966a, 5, 495-501.

Jones, S. Decoding a deceptive instruction. British Journal of Psychology, 1966b, 57, 405-411.

Jones, S. Instructions, self-instructions, and performance. Quarterly Journal of Experimental Psychology, 1968, 20, 74-78.

Just, M. A. Comprehending quantified sentences: The relation between sentence-picture and semantic memory verification. Cognitive Psychology, 1974, 6, 216-236.

Just, M. A., & Carpenter, P. A. Comprehension of negation with quantification. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 244-253.

Just, M. A., & Clark, H. H. Drawing inferences from the presuppositions and implications of affirmative and negative sentences. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 21-31.

Karttunen, L. Implicative verbs. Language, 1971, 47, 340-358.

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

Klima, E. S. Negation in English. In J. A. Fodor and J. J. Katz (Eds.), The Structure of Language. Englewood Cliffs, N. J.: Prentice-Hall, 1964.

Lakoff, R. If's, and's, and but's about conjunction. In C. J. Fillmore and D. T, Langendoen (Eds.), Studies in Linguistic Semantics. New York: Holt, Rinehart and Winston, 1971.

McMahon, L. E. Grammatical analysis as part of understanding a sentence. Unpublished doctoral dissertation, Harvard University, 1963.

Osgood, C., & Richards, M. From yang and yin to and or but. Language, 1973, 49, 380-412.

Rosenberg, S. Modelling semantic memory: Effects of presenting semantic information in different modalities. Unpublished doctoral disseration, Carnegie-Mellon University, 1974.

Rumelhart, D. W., Lindsay, P. H., & Norman, D. A. A process model for long-term memory. In E. Tulving and W. Donaldson (Eds.), Organization of Memory. New York: Academic Press, 1972.

Schank, R. C. Conceptual dependency: A theory of natural language understanding. Cognitive Psychology, 1972, 3, 552-631.

Seymour, P. H. K. Response latencies in classification of word-shape pairs. British Journal of Psychology, 1969, 60, 443-451.

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

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

Tuinman, J., & Brady, M. How does vocabulary account for variance on reading comprehension tests? A preliminary to an instructional analysis. Paper presented at the National Reading Conference, Houston, Texas, December, 1973.

Wason, P. C., & Jones, S. Negatives: Denotation and connotation. British Journal of Psychology, 1963, 54, 299-307.

CHAPTER II

Remembering the Location and Content of Sentences in a Prose Passage[1]

Joseph M. Christie[2]

and

Marcel Adam Just

Psychology Department

Carnegie-Mellon University

Pittsburgh, Pennsylvania 15213

September 26, 1975

Abstract

This paper examines how people remember the location of a sentence in a passage, and how they make use of the locative information in retrieving content information. Subjects read a passage and were questioned about the content or the location of certain items in the passage. Performance was measured by monitoring response latencies and eye fixations. Experiment I showed that subjects barely retain or use any locative information from disorganized passages that they memorize. By contrast, Experiment II showed that subjects do retain and make use of locative information for both organized and disorganized passages when the passage is in view at the time they are answering the questions. Apparently the locative information provides an index to the spatial distribution of sentences in the passage.

One of the more enigmatic skills reported by experienced readers is the ability to remember where certain information is located in passages and books. This locative information may be vague, referring to the beginning, middle, or end of a long book or much more specific, referring to a particular location on a page. Even more puzzling is that locative information is usually stored unintentionally. The locative information may even be available after the content is forgotten; students sometimes report that even though they cannot recall the answer to a quiz question, they can recall the part of the page in the textbook in which the answer is located. There are some tasks in which locative information can be very valuable, namely those in which the total content occupies a large amount of space but is physically available for inspection. In such tasks, the locative information can provide an index to the text, making the search process more efficient. This is the case in reading comprehension tests where the reader is allowed to refer back to the passage after reading a question. This study will explore the representation of locative information in memory and the unintentional use of locative information during visual search in a reading comprehension task.

When people were asked to remember the content of a 12-page prose passage, frequently they could also recall which page contained a particular fact, and what part of a page contained it (Rothkopf, 1971). The probability of recalling the content information was also correlated with the recall of within-page locative information. There are at least two different explanations for this correlation. One explanation is that readers may be able to report locative information by deducing it from their knowledge of the content. For example, after reading a passage describing a football game, the reader could deduce that information about the opening kickoff occurred at the very beginning of the passage, and the information concerning the final score occurred near the end of the passage. An alternative explanation is that readers may explicitly encode the location of a specific piece of information, in this case, the fact that the final score was printed near the end of the passage. Such locative information may be useful in organizing a representation of the passage content. Both hypotheses are consistent with Rothkopf's observed correlation. The former hypothesis deals with deductions based on content information retrieved from long-term memory while the latter hypothesis deals with initial comprehension and encoding processes.

Zechmeister and McKillip (1972) extended Rothkopf's study by examining the relation between recall of location and recall of content. Recall of content was correlated significantly with recall of location, as in Rothkopf's study. Zechmeister and McKillip also found that telling the subjects the location of the answer to a content question did not help them recall the answer. So knowledge of location is certainly not a sufficient cue for recall of content. Briefly, the two studies show: 1) incidental recall of locative information is a reliable phenomenon; 2) recall of content correlates with incidental recall of location; and 3) recall of content information is not improved by giving subjects location information.

Experiment I

Experiment I was a probed recall experiment designed to measure response latencies for retrieving either location or content information. Short prose passages (about 150-200 words long) were used. We presented both coherent passages as well as passages whose sentences were in a scrambled order. While locative information can be deduced from the logical structure of a coherent passage, it can not be deduced from the logical structure of a disorganized passage. The main purpose of Experiment I was to determine 1) how the organization of the passage (organized vs. disorganized) affects memory for locative information and memory for content information and (2) how retrieval latency varies as a function of the retrieved item's serial position in the passage.

METHOD

Materials. Three prose passages from the Sequential Tests of Educational Progress[3] (1969) and three passages from the Graduate Record Examination Aptitude Test (1973) were modified so that each passage was 11 sentences long, with each sentence taking up two lines of elite type. The disorganized versions of the six passages were constructed by randomly reordering the original sentence order. Each passage was then divided into three sectors by drawing heavy black lines between the fourth and fifth and the seventh and eighth sentences and labeling each sector 1, 2, and 3 respectively. Each sentence was also followed by the numbers 1 through 5 on the right-hand margin. These latter numbers were used in a sentence rating task described later. Table 1 shows one of the organized passages as it was presented to subjects.

Insert Table 1 about here

Both the content and location of each sentence was interrogated. The same questions were used for both Content and Locate probes. A cue word (either "content" or "locate") indicated to the subject whether he was to answer the question or to state which of the three sectors of the passage contained the answer. Examples of each type of question are:

content

Content probe: Who challenged the legality of the war?

locate

Locate probe: Who challenged the legality of the war?

Table 1

Sample Passage and Questions

Sector Number	
1	Seventy years ago, the United States fought a protracted and bloody war of counterinsurgency in the Philippine Islands. Evidence suggests that Americans initiated the fighting in 1899, two days before a treaty with Spain was to be ratified. The Americans started the fighting in order to stampede legislators balking over the provision to annex the Philippines. Maj. Gen. Elwell S. Otis assured the American public that the Filipino nationalist forces would be wiped out in a few weeks.
2	Once the fighting erupted outside Manila, Gen. Otis continually reiterated his prediction along with demands for more troops Newspapers openly accused Gen. Otis of inflating enemy body counts while concealing enormous American losses. The general returned a hero to Washington in 1900, and doubts were washed away in a sea of toasts and patriotic testimony.
3	Once home, Otis attacked the peace movement for encouraging the Filipinos to continue fighting, rather than surrender. A Republican Senator from Massachusetts, George F. Boar, became a leading dove and challenged the legality of the war. Despite the Army's censorship, correspondents corroborated suppressed rumors of American atrocities in the Philippines. Civilians were being slaughtered, herded into concentration camps, tortured to extract information, and shot as hostages.

Table 1 -- Continued

Serial Position of Interrogated Sentence	Question
1	Where did the U. S. fight a war seventy years ago?
2	Who initiated fighting before a treaty was signed?
3	Why did Americans start fighting in the Philippines?
4	Who was to be wiped out in a few weeks?
5	What city did fighting erupt outside of?
6	Who accused General Otis of inflating enemy body counts?
7	Where did General Otis return to, as a hero?
8	Once home, who did General Otis attack?
9	Who challenged the legality of the war?
10	What did correspondents corroborate in the Philippines?
11	Who was herded into concentration camps?

In answer to the Locate probes, subjects responded "one", "two", or "three" to designate which of the three sectors in the passage contained the answer to the question. Subjects responded "Don't Know" if they were unable to respond otherwise. The Content and Locate trials were randomly interspersed.

Design and Procedure. The following factors were combined orthogonally: 2 probe types (Content and Locate), 11 sentence locations, 2 passage types (organized and disorganized), and 3 exemplars of each type of passage. Five of the ten subjects received three randomly chosen passages in organized form and the three remaining passages in disorganized form, so that a subject saw a passage in only one of its two possible forms. The remaining five subjects saw the same passages except that the organized passages were replaced with the corresponding disorganized passages and vice versa.

Each subject was instructed to read the passage sentence by sentence, and use the 5 point scale to rate how well each sentence contributed to the development of the passage. This rating task was used to encourage subjects to process each sentence in relation to the preceding portion of the passage. Subjects were allowed as much time as they needed to complete this task, usually about four to five minutes. Following reading of the passage and completion of the rating task, all the questions associated with that passage were asked. The questions were presented in a random order in a tachistoscope. Subjects were timed while they read the question and responded vocally into a throat microphone, activating a voice operated relay which stopped a clock. Subjects were told to answer as quickly as possible without sacrificing accuracy, and to respond "Don't Know" if they were certain they did not know the answer to the question. Latencies for incorrect responses were recorded but not used for analysis. The probes were exposed in the tachistoscope at a distance of 58 cm and subtended no more than 13° of visual angle.

The order of presentation of six passages was randomized with the constraint that each consecutive pair of subjects received all six passages in all of their twelve possible forms. The ten volunteer subjects were college students.

RESULTS

Missing cells for the response latency data (either errors or Don't Know responses) accounted for 11.8% of all the observations and were replaced by least square estimates, assuming additivity of the main effects. For the Content questions, the mean latencies were similar for organized passages (4.469 sec) and disorganized passages (4.644 sec), $F(1,9) = 1.31$, n.s. Because the same passages occur in organized and disorganized forms for different subjects, this comparison does not involve the language-as-fixed-effect fallacy (Clark, 1973). Figure 1 shows the mean response latencies for the Content questions as a function of the interrogated sentence's serial position in the passage.

Insert Figure 1 about here

The latency to answer a Locate question was considerably shorter for the organized passages (3.689 sec) than for the disorganized passages (4.235 sec), $F(1,9) = 12.66$, $p < .01$. Figure 2 shows the mean response latencies for the Locate questions as a function of the interrogated sentence's serial position in the passage. The Locate latencies for disorganized passages were especially long at serial positions 4, 5, 6, and 7.

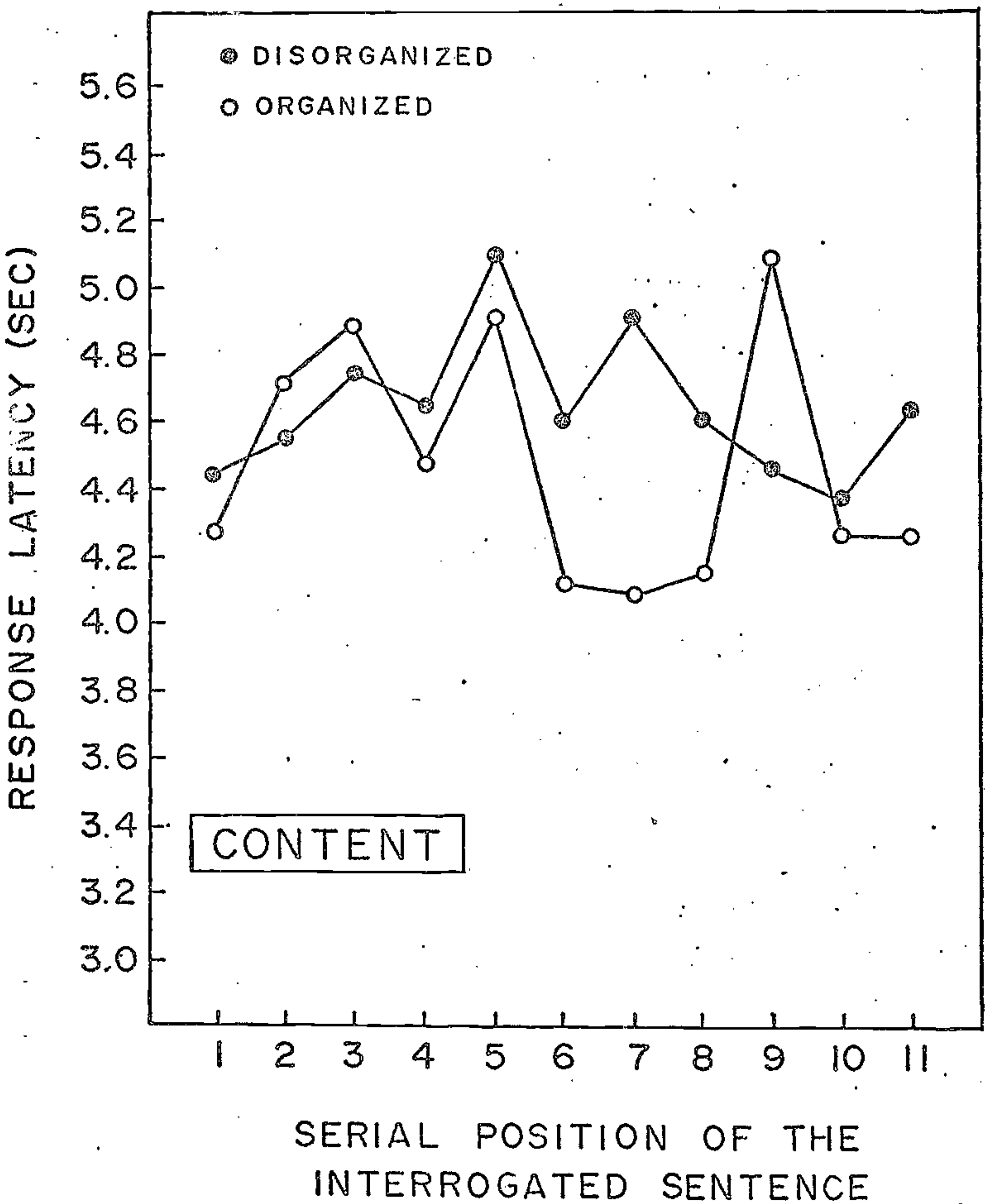


Figure 1. Mean response latencies for Content probes in Experiment I.

This result will prove to be of particular interest.

Insert Figure 2 about here

The mean response latencies for the Locate questions (3.962 sec) were significantly shorter than the latencies for the Content questions (4.556 sec), $F(1,9) = 29.38$, $p < .01$. This difference cannot be attributed to the time to read the questions, since the questions were the same for the Content and Locate trials.

The proportion of erroneous responses and Don't Know responses for the various conditions are shown in Table 2. There were almost twice as many Locate errors for disorganized passages (33%) as for organized passages (18%). Content questions produced more Don't Know responses than erroneous responses, while Locate questions produced more erroneous responses than Don't Know responses. Apparently subjects knew when they could not recall content information and responded "Don't Know" rather than give an erroneous response. However, subjects guessed rather than admit lack of knowledge when probed about location information, perhaps because the number of location responses was limited to three alternatives, while the responses for content probes were open-ended.

Insert Table 2 about here

DISCUSSION

Several conclusions can be drawn about the relation between locative and content information. First, retrieving locative information does not seem to be an essential pre-requisite for retrieving content information. In other words, you don't have to know where the information was located

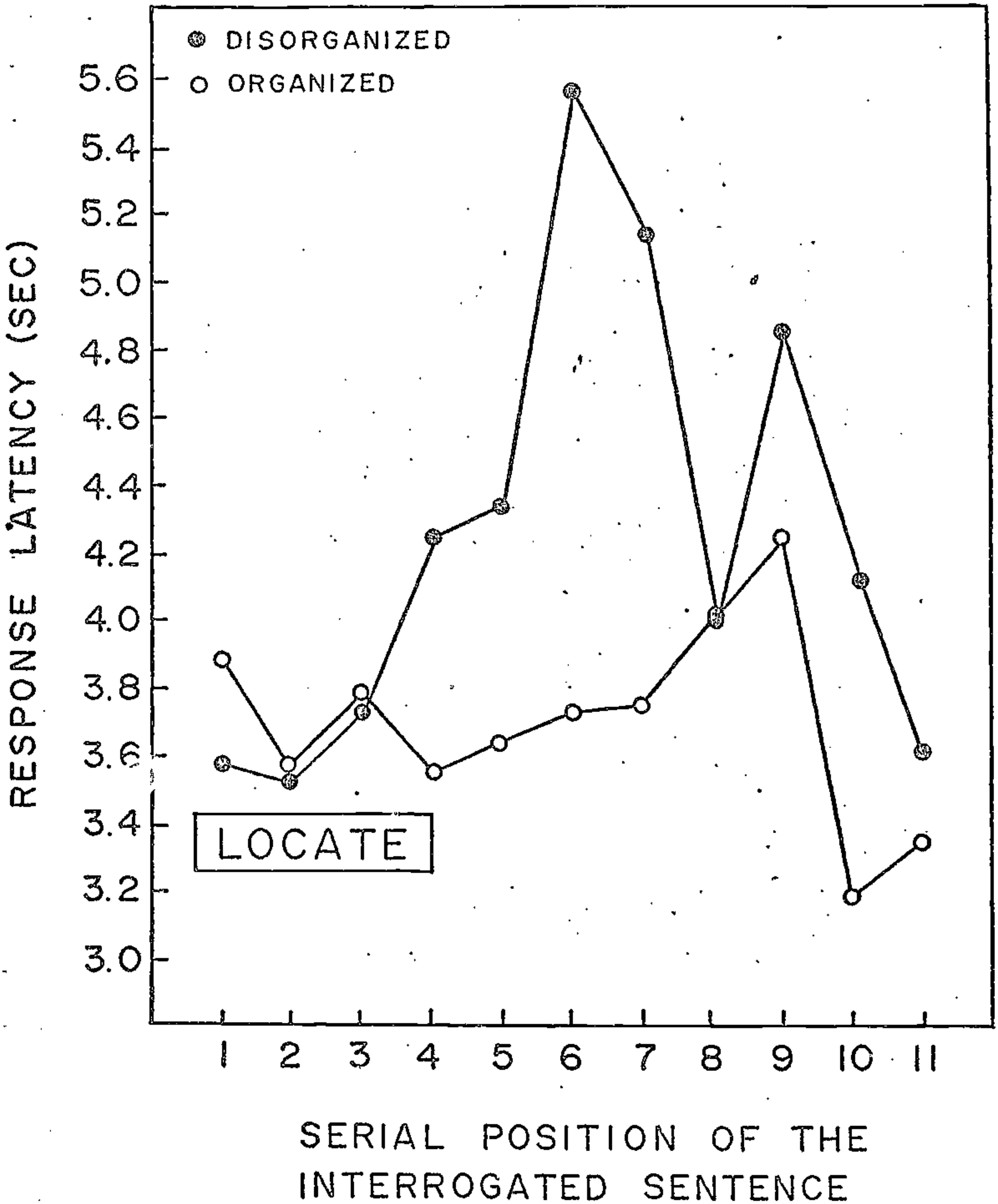


Figure 2. Mean response latencies for Locate probes in Experiment I.

Table 2

Proportion of Erroneous Responses and Don't Know Responses

Response Type	Question Type	Passage Type: Organized	Disorganized	Mean
	Content	.06	.07	.07
Erroneous	Locate	.18	.33	.21
	Mean	.12	.20	
	Content	.13	.11	.12
Don't Know	Locate	.03	.03	.03
	Mean	.08	.07	

in order to retrieve it. This conclusion follows from the pattern of latencies obtained for the disorganized passages. The Locate latencies for the disorganized passages at positions 6 and 7 were substantially (581 msec) longer than the corresponding Content latencies. Since the Locate latencies are longer, retrieving location cannot be a component of the process that retrieves content, at least for these passages. But this is not to say that location information is not used in some situations to help retrieve content information, but merely that it does not have to be used.

The latencies to respond to a Content question were similar for the organized and the disorganized passages. This suggests that subjects may represent the two passages similarly, perhaps by reorganizing the information from the disorganized passages. This in itself is not a startling conclusion, but it does have some interesting implications. It implies that internal reorganization of the sentences of a disorganized passage should destroy some of the locative information in the passage, so that subjects should have difficulty in recalling which part of a disorganized passage a sentence came from. This was certainly the case. The Locate latencies were over half a second longer when the passage was disorganized. This supports the conclusion that the disorganized passage is reorganized in memory.

A third conclusion is that the content of the passage is not stored as an ordered list, for if it were, then one might expect some systematic serial position effects. As Figure 1 shows, there were no systematic serial position effects in recalling the content of either organized or disorganized passages. Rather than a list, the passage content is probably stored as an interconnected network structure, whose nodes are single propositions, and the links are inter-propositional connectives denoting relations like causality or temporal sequence.

Experiment II

Experiment II was designed to unobtrusively measure memory for location by recording subjects' eye fixations as they scanned a previously-read passage in search of an answer to a Content question. Subjects read passages such as those in Experiment I (with location boundaries and sentence rating numbers deleted) solely for information about content. Subjects first read the passage at their own rate and then answered oral questions about the content of the passage. They were permitted to look back at the passage when answering the questions. The subjects' initial fixations should indicate where they thought the desired information was located. This paradigm has several advantages. First of all, the locative information serves a useful function in this task in that it provides an index to the visible passage. Secondly, the locative information should be stored incidently, and made use of without explicit mention of it. Thirdly, the familiar reading comprehension task plays an important role in evaluating academic ability and achievement, so it is an ecologically valid task.

This task requires subjects to compare the probe question to their knowledge about the paragraph and either respond with information stored in memory or search the passage for the answer to the probe. Of central interest to this study is the use of stored locative information in a visual search task. If information about location is available in memory but the corresponding content information is not, the locative information could provide an index to the spatial distribution of information in the passage. Locative information could be used either to fixate the interrogated information in the very first fixation or to guide an extended search consisting of several fixations. Visual search for information in disorganized passages may take longer either because of lack of locative information or inaccuracy of stored locative information.

A number of measures from the visual search paradigm are of interest in this study. How accurate is the initial eye fixation with respect to the actual location of the probed information? Does passage organization play a role in visual search for information? Do subjects use locative information to guide extensive visual searches? The answers to these questions should provide a clear statement about the use of locative information in reading comprehension.

METHOD

Experiment II made use of the same materials as Experiment I. The main distinguishing properties of Experiment II were (1) only Content questions were asked, (2) the passage was presented on a standard video monitor and the subjects' eye fixations were recorded, and (3) the questions were presented orally.

Eye fixations were monitored with a corneal reflectance eye camera. The eye spot was electronically superimposed on a picture of the stimulus display, and the composite was recorded on videotape for later scoring. The entire passage subtended about 24° of visual angle in the horizontal axis and 19° in the vertical, but this varied from subject to subject as the viewing distance was adjusted between 53 and 68 cm.

Procedure. Subjects were instructed to read the prose passage solely for content with no mention about the location of information in the passage. The test passage was presented on a video monitor. After the self-paced reading period, the passage was switched off the monitor screen. During this off-period the monitor screen was blank. The 11 trials (one for each sentence in the passage) began immediately afterward. The spot was calibrated before each trial when subjects were asked to fixate the bottom center of the screen. A trial consisted of a question phase, when the oral probe was presented while the monitor was blank, followed immediately by a visual search phase, during which the passage was presented on the monitor. The visual search phase was terminated when the subject ended his vocal response to the question. At that time, the passage was switched off again. Response latencies were determined by measuring the interval between the end of the question (which was simultaneous with the onset of the passage) and the beginning of the response. The interval was measured with a stopwatch from the audio portion of the recording of the session.

Subjects. The 6 subjects were college students who were paid for one experimental session. Data from four other subjects could not be used because of excessive head movements resulting in unstable eye spots. All subjects had normal, uncorrected vision and wore no corrective lenses.

RESULTS

Subjects remembered the location of the interrogated sentence quite well. After they heard the question, their initial fixation on the passage was at the interrogated sentence 31% of the time for organized passages, and 19% for disorganized passages. Chance level is 9%. Figure 3 shows the mean location initially fixated as a function of the serial position of the interrogated sentence. The data indicate that even when the first fixation is not at the correct location, it is generally close to the correct location. If the subjects' first fixation were always at the correct location, then their data would fall along the dashed diagonal line in Figure 3. As it is, they are fairly close. One of the points plotted in Figure 3 deserves special mention. The mean initial fixation location for serial position 3 of the disorganized passages seems to be discrepant. However, there is a very interesting explanation behind this datum. Some of the passages contained more than one sentence that referred to a particular character. Consequently, when the probe asked about that character, there was more than one appropriate location to fixate in the passage, although only one location was "correct" in the sense that it contained the answer to the probe. Almost all the "incorrect" fixations at serial position 3 for disorganized passages are accounted for by this factor. The result suggests that subjects did store an appropriate location even for the condition that appears at first to be discrepant.

Insert Figure 3 about here

The accuracy of the first fixation was similar for the organized and disorganized passages. However, when the initial fixation was inaccurate, the subsequent search was much more efficient for the organized passage. This was demonstrated by counting the number of fixations before the response was made. In this analysis, any consecutive fixations on the same sentence were counted as a single fixation. A change in fixation was scored only if there was a vertical change in eye fixation position, namely from one sentence to another. As Figure 4 shows, visual search is facilitated when the passage is organized rather than disorganized. On average, there are about 1.5 fewer fixations for the organized passage. The relative advantage of the organized passage is most apparent for the middle serial positions.

Insert Figure 4 about here

The response latencies in this task presented an excellent opportunity to examine the role of locative information in this approximation to the reading comprehension test. If the answers to the questions are retrieved much as the answers to a memorized passage are, then the response latencies

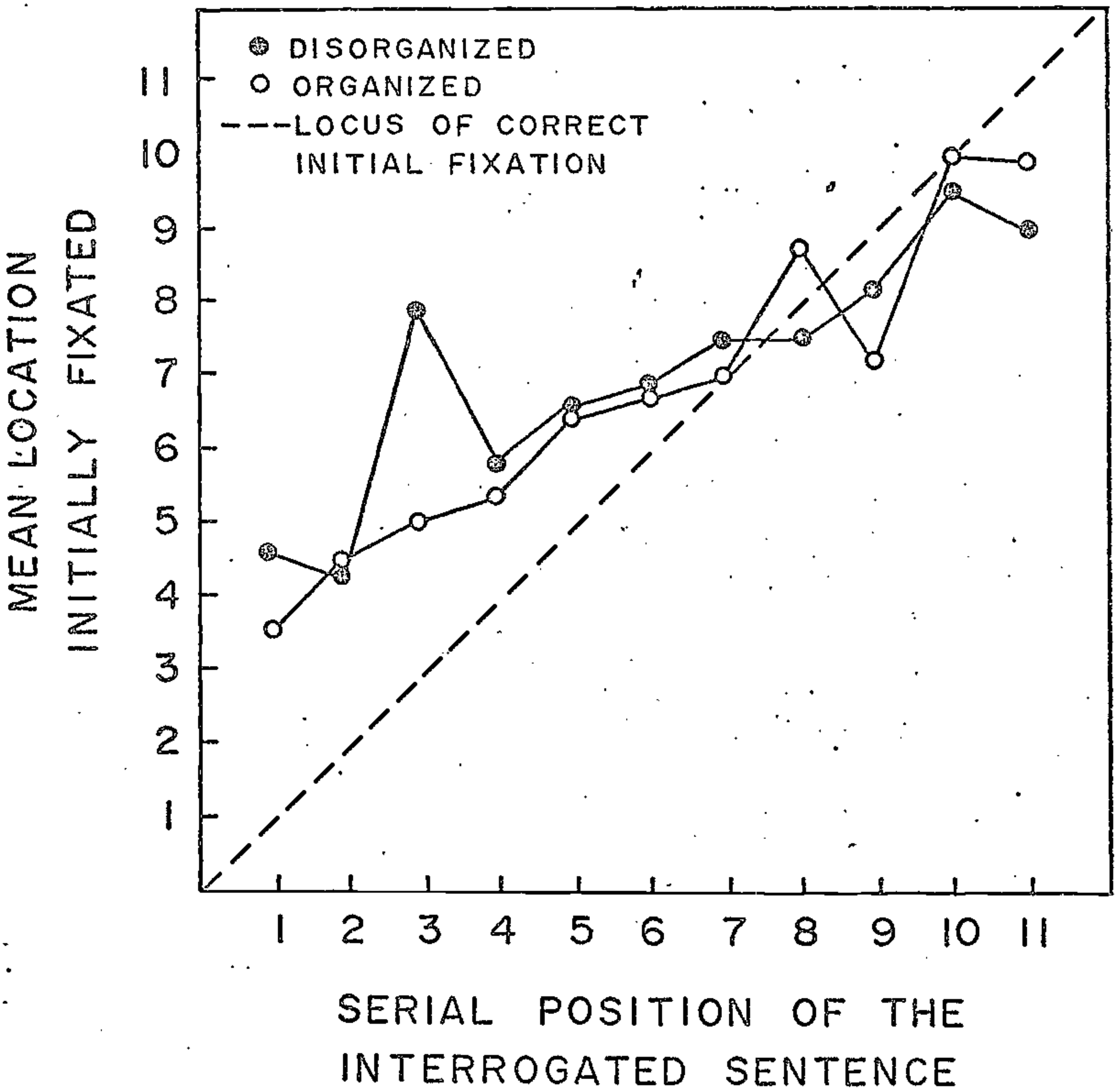


Figure 3. Mean locus of the initial fixation as a function of the serial position of the interrogated sentence in Experiment II.

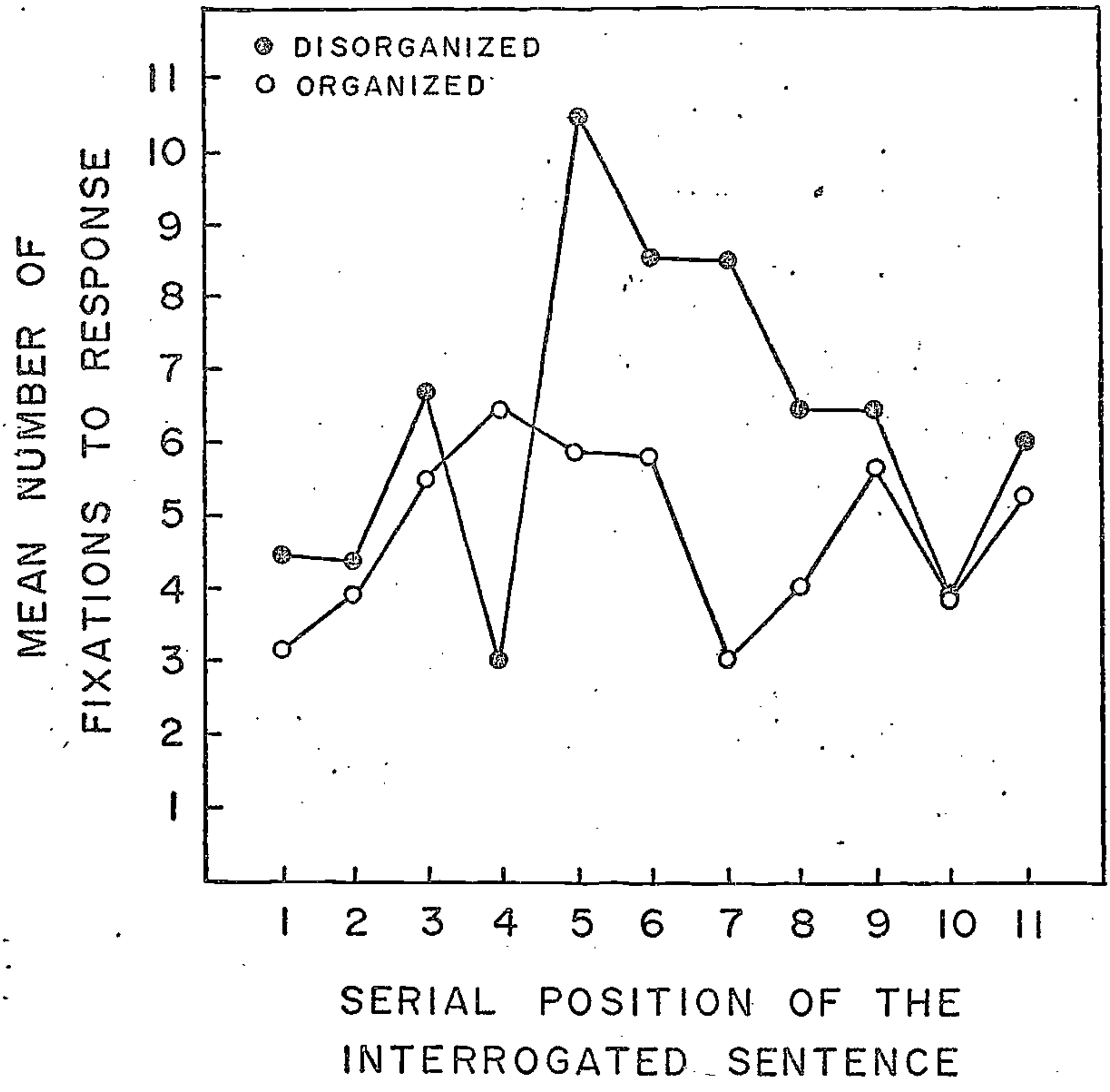


Figure 4. Mean number of fixations to response in Experiment II.

should resemble the Content latencies in Experiment I. However, if the answers to the questions are retrieved by computing the location information and then using that information to guide the visual search for the answer, then the response latencies should resemble the Locate latencies in Experiment I. As Figure 5 shows, the shape of the serial position curves for the response latencies in Experiment II closely resembles the Locate latencies in Experiment I (shown in Figure 2), although the mean latency and the range of latencies is higher in Experiment II. The shape of the curves in Figure 5 also resembles Figure 4. Thus the visual search time and the number of fixations observed in Experiment II closely resemble the duration of the internal search for Location information observed in Experiment I. The implication is that the internal search processes on Locate trials in Experiment I resemble the external search processes in Experiment II.

Insert Figure 5 about here

Despite presence of the passage, 9.6% of the responses were erroneous in the organized passage condition and 3.0% in the disorganized passage condition. Since the passage was visible to the subject, there was no occasion for Don't Know responses.

DISCUSSION

The eye fixation behavior showed that subjects accurately remembered the location of sentences in a passage. Moreover, the accuracy of the locative information (as gauged by the accuracy of the initial fixation) was as good for disorganized as for organized passages.

After the initial fixation, visual search was more efficient for organized passages than for disorganized ones. If a subject is being tested on an organized passage, and his initial fixation is inaccurate, then he

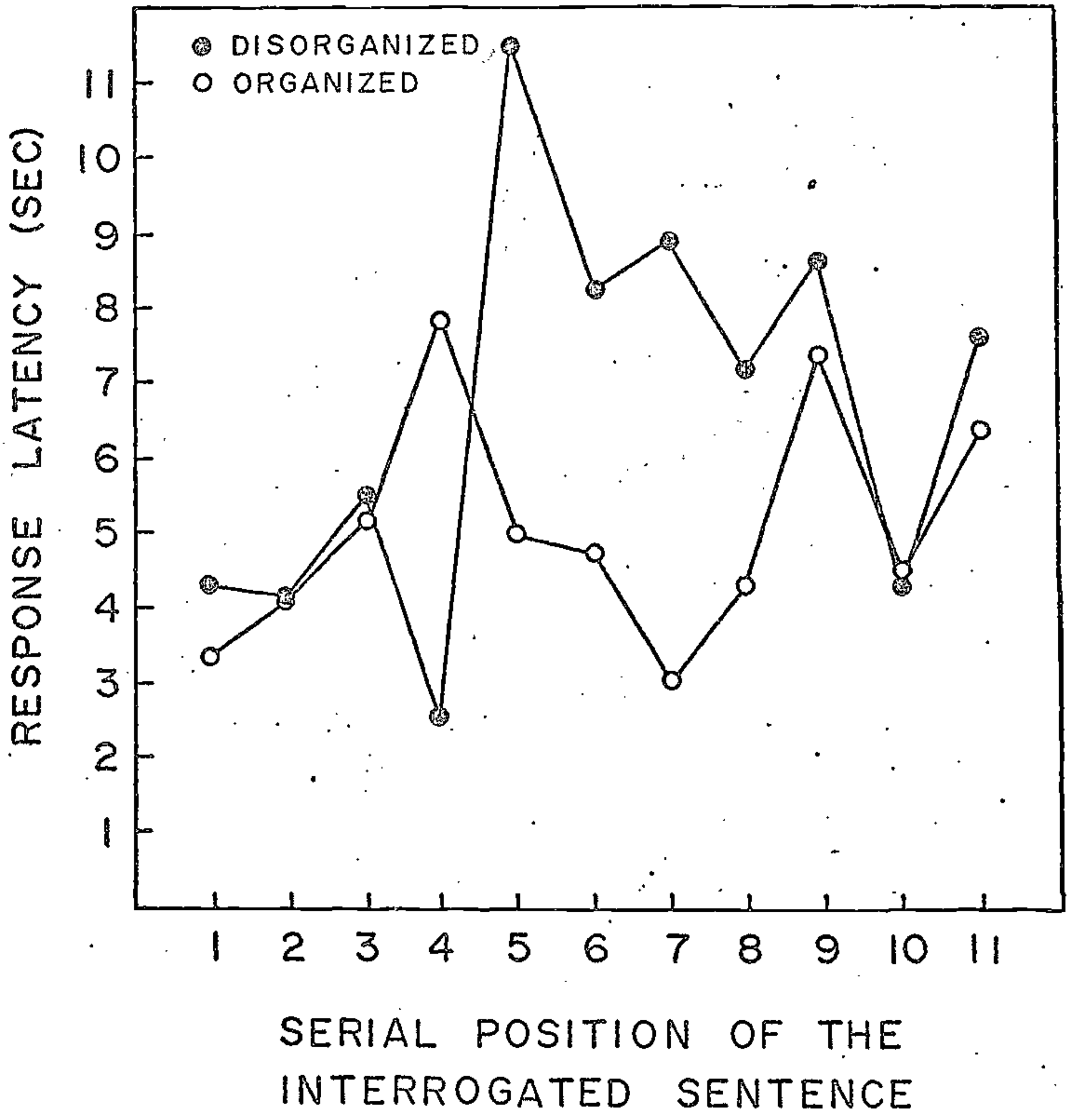


Figure 5. Mean response latencies in Experiment II.

knows pretty well where to look next. There are two possible sources of this knowledge. First, it is possible that what he read at the incorrect location provided a cue to the location of the appropriate sentence. For example, if the question were Which team was ahead after three quarters? and the sentence at the incorrect location said The home team was losing at half-time, then the subject would know to look somewhere further down in the passage. He could make this deduction because events that occur later are often described later. Another possible source of knowing where to look would be his previous memory for the passage. If he could recall in approximately what order the events were described, then by fixating an inappropriate sentence, he could estimate the position of the interrogated sentence, by considering their relative order of occurrence.

However, in disorganized passages, both these sources of information would tend not to function. If the sentences are in a scrambled order, then they do not follow any natural sequence, and any sequence they do follow would be difficult to encode and store. So the information from the initial fixation that is inaccurate also fails to provide any guidance to subsequent visual search. Thus, even though the accuracy of the initial fixation is similar for organized and disorganized passages, the efficiency of the subsequent visual search is much greater for the organized passages.

One possible reason for the good memory for location is that each test trial could be considered an additional learning trial. There are 11 test trials following each passage, in addition to the original study period that the subject was permitted to determine for himself. Regardless of the source of the location information, it is very clearly there and it is put to use in retrieving information from the passage.

The two experiments together indicate the role of locative information in the storage and retrieval of information from a passage, and they also indicate how the locative information is related to the internal structure of the passage. When a passage is coherent, as most passages we read are, then people internalize the structure of that passage. That is, they encode how the various propositions in the passage are related to each other. In a coherent passage, the temporal sequence in which the sentences occur generally corresponds to the logical sequence that relates the sentences. In memorizing or skimming a passage in order to do a reading comprehension test, both the logical relations among the sentences and the location of the sentences are stored. The function of the locative information is that it serves as an index to the content information, both in the cases when the content is stored internally and when it is stored in an external display. The locative information tells the subject where to look for the information he wants.

When passages are disorganized, then subjects tend to internally reorganize them in order to remember them. This reorganization involves a sequence of propositions that is different from the presented sequence of corresponding sentences, so that the locative information is not preserved. Thus there is poorer memory for location in disorganized passages that must be memorized.

Finally, this paper points out the potential value of eye fixation research in investigating cognitive processes. The eye fixation behavior reveals the sequence in which information from an external display is accessed, and can also indicate how much time is spent processing the information from each part of the display. Although there is a long history of eye fixation research in the study of reading, it remains to apply this powerful tool to the study of verbal cognitive processes that involve reading comprehension.

REFERENCES

Clark, H. H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 335-359.

Graduate Record Examination Aptitude Test. New York: Simon and Schuster, 1973.

Rothkopf, E. Z. Incidental memory for location of information in text. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 608-613.

Sequential Tests of Educational Progress, Series II, Reading Form 2A. Princeton, N. J.: Educational Testing Service, 1969.

Zechmeister, E. B., & McKillip, J. Recall of place on the page. Journal of Educational Psychology, 1972, 63, 5, 446-453.

FOOTNOTES

1. This research was supported in part by Research Grant NIE-G-74-0016 from the National Institute of Education, and Grant MH-07722 from the National Institute of Mental Health. We thank Patricia Carpenter for her comments on the project. Requests for reprints should be sent to Marcel Adam Just, Psychology Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.

2. Now at the Department of Psychology, Stanford University, Stanford, California.

3. We thank Tom Donlon of Educational Testing Services for providing this material.

CHAPTER III

Integrative Processes in Comprehension[1]

Patricia A. Carpenter

and

Marcel Adam Just

Department of Psychology

Carnegie-Mellon University

Pittsburgh, Pennsylvania

To appear in: D. LaBerge and S. J. Samuels (Eds.), Perception and Comprehension. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976 (in press).

Even though we acquire much of our knowledge by reading or listening to other people, we sometime have difficulties in understanding them. The problem often lies _not_ in understanding the words that the other person is using, but in understanding "what the speaker is talking about." These difficulties arise in understanding how the words and clauses in a sentence are related to other sources of information, such as the previous sentences in the discourse. One example of this interrelation among sentences is the use of a pronoun to refer back to a previously mentioned item. For example, if the sentence _He just bought a car_ occurs within a paragraph, then the referent for _he_ must have been previously established. Comprehension in context requires more than understanding that _he_ refers to an animate male, probably human. It requires that the comprehender determine the referent of _he_. This is an example of what we mean by relating the information in the sentence to other knowledge in order to understand "what it is about." This paper will examine the process by which the information in the sentence is related to other sources of information, such as a preceding paragraph, a question, or the perceptual context. We will also examine a number of linguistic devices that indicate how the sentence is related to its context; and how the linguistic cues are used during comprehension.

To talk about the psychological process of integrating information, we will introduce the concept of a discourse pointer. A discourse pointer is a symbol in the comprehender's mind that indicates the current topic of the discourse or the perceptual context. The discourse pointer activates either a single concept or an entire relational structure. The activated constituent then plays a central role in how the currently comprehended sentence is integrated with other information. We will show that the function of a number of linguistic devices used in discourse is to set the pointer appropriately. The appropriate placement and movement of the pointer during discourse makes sentences of a well-written paragraph seem to flow smoothly.

While we will primarily discuss integrative processes from the viewpoint of psychological processes and linguistic structures, we will also discuss the integrative devices from a third viewpoint--namely the rules for writing comprehensible prose. Teachers of prose composition have provided some rules of "good writing". These rules are often concerned with the linguistic devices that make sentences fit together. We will show how their analyses are based on implicit models of human comprehension processes. Many of the guidelines can be thought of as rules for setting the discourse pointer of the reader. We will examine these rules and relate them to psychological models of the reader's comprehension processes.

As an initial example of the psychological function of the discourse pointer, consider the process of comprehending a very simple paragraph:

> Cecil, the aardvark, was a perfect pet. Because of his exotic eating habits, he was able to rid the house of

> insects. What he devoured most often were the fat, juicy ants. Moreover, he was an affectionate animal. However, because of his ugly snout, he was difficult to love.

Various linguistic devices in this paragraph set the discourse pointer and indicate how the sentences relate to one another. The opening sentence initially sets the discourse pointer to the proposition that the aardvark is a good pet. Opening sentences play a major role in paragraph comprehension because they determine the initial state of the pointer. The initial state may also serve as a default state, to which the pointer returns unless it is explicitly set to another concept or proposition. That is why it is important to place topic sentences at the beginning of paragraphs.

The second sentence exploits the preceding context by referring to the aardvark with the pronoun he. The discourse pointer moves to a pair of propositions that describe the nature and consequences of the aardvark's eating habits. The third sentence presupposes that Cecil devours things. This presupposition matches the contents of the discourse pointer. The third sentence also adds the new information that the insects most often eaten are ants. The comprehension of this sentence depends upon already having established that Cecil eats insects. The connective moreover signals a return to the main line of argument about Cecil's good pet qualities. The however in the final sentence signals an opposing argument to the thesis that Cecil is a good pet. Thus, the reader is given an indication of how to relate the sentence to the representation he has constructed from the previous discourse. This short paragraph provides a number of examples of linguistic devices that determine the relations between sentences. This paper will explore these devices in terms of how they interact with the discourse pointer during integrative processes.

This paper consists of two main sections. One section will present a series of studies examining how the information designated by the discourse pointer influences the comprehension of a sentence. A second section will examine various linguistic devices that make prose comprehensible and memorable. But before discussing integrative processes, we will first examine some of the methodological issues that arise in organizing the diversified research on comprehension.

Psychological processes and experimental paradigms

In order to interrelate the numerous research approaches to prose comprehension and memory, we have devised a taxonomy (shown in Table 1) that has two dimensions. One dimension concerns the psychological processes of interest, namely comprehension processes or memory processes. The second dimension concerns the particular performance that is measured, for example reading time or amount of recall.

- - - - - - - - - - - - - -

Insert Table 1 about here

- - - - - - - - - - - - - -

The distinction made by the first dimension between ongoing comprehension and memory is more complex than it first appears to be. Comprehension refers to processes that operate at the time of input, while memory refers to the storage and retrieval of the comprehended information. The complexity is that what is stored depends on what was comprehended. Thus, performance in a memory task may reflect either comprehension processes or subsequent memory processes or both (cf., Fillenbaum, 1973). For example, recall or recognition memory for a

Table 1

Processes and Performance Measures in Prose Research

Processes	Performance Measures
	reading time
	verification time
Ongoing comprehension	shadowing lag or accuracy
	eye fixations
	protocol analysis
	prompted or free recall
Memory	recognition memory
	answering questions about a text

passage may reflect the output of integrative processes in comprehension or the output of reconstructive processes in retrieval.

Some of the performance measures listed in the second dimension of the taxonomy are especially suited to the study of integrative processes during comprehension. The mental operations of chief interest are those that find and represent higher-order relations between constituents such as clauses and sentences. The duration of these integrative processes is very short; under optimal circumstances, it may take only a fraction of a second to determine how one sentence is related to another. In order to tap into these rapid mental operations, it may be necessary to monitor the processes as a sentence is being read and integrated with the previous ones. One such methodology (to be reported in this chapter) asks the reader to read each succeeding sentence of a passage and decide if it is consistent or inconsistent with the previous sentences. The decision times can be analyzed as a function of the semantic and anaphoric relations between the current sentence and previous ones. This methodology gives some measure of the duration of an integrative step. Another possible approach is to monitor eye fixations during reading. The duration of fixation on a particular constituent may reflect how long it takes to relate that constituent to previous information from the passage. Furthermore, regressive eye movements to previous mentions of a concept may externalize the search for the constituents to be integrated. By directly monitoring the integrative process, these methodologies may reveal the nature, sequence, and duration of the mental operations that are used in integration.

Relating new information to old information

Each sentence of a connected discourse contains both some new information as well as some old information that is redundant with the preceding sentences (cf., Chafe, 1970; Halliday, 1967). The new information fulfills the function of communicating new knowledge. By contrast, the primary role of the old information may be integrative (cf., Haviland & Clark, 1974). But how does the reader know what information is old and what information is new? The distinction must be communicated because the two kinds of information are treated quite differently during comprehension, as we will document below.

There are various linguistic devices that signal to the reader which constituents are old and which are new. In fact, the linguistic structure that a writer uses depends upon what he thinks his reader already knows and what he is trying to communicate as new information. Consider the writer who wants to say something about the event of John painting a barn. If the reader has already been told that John painted something, but does not know precisely what was painted, the writer might say "It was a barn that John painted" but not "It was John who painted the barn." By contrast, if the reader knew that the barn had been painted, but did not yet know who painted it, the writer might say, "The one who painted the barn was John." Thus the same event would be described differently, depending on the listener's previous knowledge state. In spoken English, we often use vocal contrastive stress to indicate the new information (Halliday, 1967). For example, the speaker might stress the word <u>John</u> in a sentence like <u>JOHN painted the barn</u> if the main new information were the identity of the painter. These examples illustrate how the information structure of an appropriate sentence can be tailored to the reader's prior knowledge.

This linguistic marking of the old and new information has an important consequence for the discourse pointer. The marking distinguishes between information that should be added on in memory and information that should be used in determining the relation between the current sentence and previous information (cf., Haviland & Clark, 1974). In the course of comprehending the sentence, the pointer should be set to the structure to which information will be added. That is, the pointer should be set to the information that is old. To demonstrate how the linguistic structure of a sentence must be congruent with the state of the discourse pointer, we examined the comprehension of some linguistic structures that explicitly mark which information in the sentence is new.

Cleft and pseudocleft sentences, which occur primarily in written rather than in spoken English, stress the old-new distinction. A cleft sentence presents the new information in the introductory clause, for example, It is John who painted the barn marks John as new information. In a pseudocleft sentence, the new information comes at the end of the sentence, for example, The one who painted the barn was John. It is possible to vary the semantic role of the new constituent. As an example, we have listed the cleft and pseudocleft constructions where either the agent or object is the new information (indicated by underlining).

Pseudocleft agent: The one who painted the barn was John.

Cleft agent: It was John who painted the barn.

Pseudocleft object: What John painted was the barn.

Cleft object: It was the barn that John painted.

The new information is presented with the assumption that it hasn't been previously mentioned and can't be inferred from the previous context. The previous context could be immediately preceding discourse, the nonverbal context of the communication, or it could be the listener's prior knowledge. Regardless of the original source of the old information, the speaker has means at his disposal to mark the old and new components such that they correspond to the listener's state of knowledge.

Relating a sentence to a preceding picture

To examine how the information structure of a sentence relates it to its context, we studied the comprehension of a sentence that was preceded by a picture. The picture depicted only one person. This contextual information should set the discourse pointer to a representation of that person. Then, the sentence was presented; it described the relative positions of the depicted person and another pserson. The sentence should be easy to integrate if its linguistic structure marks as old the constituent designated by the discourse pointer. By contrast, the sentence should be difficult to comprehend if it marks as old a constituent that does not correspond to the setting of the pointer.

The subjects were told that the sentences always concerned two people, John and Barb, who were walking in a line either from left to right or right to left. They were first shown a line drawing of a male or a female (John or Barb) facing either to the left or to the right. Then, they were shown a sentence like The one who is leading Barb is John. Figure 1 shows a typical picture and sentence. The subject had to indicate whether the person not depicted would be to the left or right of the depicted person. In the example shown in Figure 1, the subject would answer that John was on the left, by pushing the left-hand response button. The critical variable was whether the picture depicted the information that the sentence marked as old or new. Responses should be faster when the person shown in the preceding picture was also the person marked as old in the sentence.

- - - - - - - - - - - - - -

Insert Figure 1 about here

- - - - - - - - - - - - - -

All four sentence types, cleft agent, cleft object, pseudocleft agent, and pseudocleft object were combined with the verbs leading and following and the two orders of names, Barb--John and John--Barb, for a total of 16 possible sentences. The 16 sentences and the 4 possible pictures (John or Barb facing right or left) produced 64 different picture-sentence combinations. Twelve Carnegie-Mellon undergraduates went through three blocks of 64 randomly ordered trials. The picture appeared in the upper channel of a tachistoscope for half a second, then disappeared as the sentence was displayed in a channel immediately below until the subject responded.

Results. Responses were faster (by 189 msec) when the sentence marked as old the person shown in the picture, F (1,11) = 43.08, $p < .01$. The mean latencies are shown in Table 2.

- - - - - - - - - - - - - -

Insert Table 2 about here

- - - - - - - - - - - - - -

The main effect was highly consistent across subjects; all 12 of them responded faster when the picture depicted the old information. As Table 2 shows, the effect occurred for six of the eight sentences. The exceptions were the cleft agent sentences like It is John who is leading/following Barb, where the responses were faster when the picture depicted the information marked as new in the sentence. It is possible that with practice, our subjects treated the cleft agent sentences like

The one who is leading Barb is John.

Figure 1. An example of a picture and subsequent sentence that were used as stimuli in Experiment 1.

Table 2

Mean Response Latency in msec and (% error)

in Picture-Sentence Experiment

Stimulus Sentence	Picture Depicts Old		Picture Depicts New	
Pseudocleft agent The one who is leading/following Barb is John.	2447	(2%)	2764	(6%)
Pseudocleft object The one who Barb is leading/following is John.	2355	(2%)	2780	(4%)
Cleft agent It is John who is leading/following Barb.	2276	(4%)	2164	(4%)
Cleft object It is John who Barb is leading/following.	2622	(6%)	2750	(7%)
	2425		2614	

simple actives, which they resemble. Such an interpretation would be consistent with the obtained result.

In general, performance is facilitated when the old-new information structure of the sentence corresponds to what is pragmatically old and new to the reader. The previous context establishes what information is pragmatically old. In the current task, the reader knew that two people were walking in a line. The picture established the direction of walking and the identity of one of the people. Thus, a picture such as the one in Figure 1 would set the discourse pointer to the propositions (WALK, BARB) & (LEFT, WALK). The information marked as old in a succeeding sentence should be compatible with the contents of the discourse pointer. For example, the information marked as old in The one who is leading Barb is John is that Barb is being lead. The fact that Barb is being lead can be related to the contents of the discourse pointer because they both concern Barb's position. The next step is to add on the new information in the sentence, namely that John is ahead.

The integrative process is more difficult when the sentence is inappropriate to the pictorial context. For example, when preceded by the picture in Figure 1, the sentence The one who is following John is Barb is inappropriate. The information marked as old in this sentence is that John is being followed. It is difficult to relate this fact about John to the discourse pointer, which concerns Barb's position. The reader must discover this mismatch and reinterpret the sentence before adding on the new information in the sentence. It is this mismatch and reinterpretation that results in the longer latencies for sentences that are inappropriate to the context.

The discourse pointer in paragraph comprehension

The discourse pointer should play an especially important role in integrating the sentences of a paragraph. In particular, the setting of the discourse pointer by an early sentence should influence the comprehension of subsequent sentences that refer back to it. To study this comprehension process, we monitored the integration of each successive sentence of a paragraph. The sentences were presented and removed one at a time, and the subject was asked to judge whether each sentence was consistent or contradictory with the preceding sentences. The response latency should provide a measure of the integrative process. We varied the semantic relation between an early sentence and a subsequent sentence and examined the effect of the relation on the response latency. We constructed 32 simple paragraphs that shared certain structural properties; a typical paragraph is:

1. The ballerina captivated a musician in the orchestra during her performance.

(target) 2. The one who the ballerina captivated was the trombonist.

3. It was the conductor who arranged the choreography.

4. The ones who prepared the show had worked long hours.

5. It was the stagehand who arranged the choreography.

The opening sentence always described how a person interacted with some unspecified member of a group. In the example above, the ballerina interacted with an unspecified member of the orchestra. This sentence initially set the discourse pointer to information that was relevant to a later target sentence. The target sentence provided new information as to the identity of the member of the group. In the example above, the target sentence appears in position 2 and specifies that the orchestra member was the trombonist. This target sentence was to be integrated with the opening sentence. A target sentence with a congruent information structure marks as old the information that had been communicated in the opening sentence. For example, the congruent target in the paragraph above marks as old the fact that the ballerina captivated someone, a fact communicated in the opening sentence. An example of an incongruent target would be The one who captivated the trombonist was the ballerina; this sentence incorrectly marks as old the fact that the trombonist was captivated by someone. In the latter case, the reader must detect the incongruity and reinterpret the sentence before integrating the new information.

A second way in which we varied the relationship between the discourse pointer and the target sentence was by inserting intervening sentences between the opening sentence and the target. That is, the target sentence could appear in positions 2, 3, 4, or 5. The filler sentences were only tangentially related to the opening sentence. The intent of the slightly incoherent filler sentences was to dislodge the pointer from the representation of the opening sentence. Thus, when the target sentence was separated from the opening sentence by fillers, its old information would not be compatible with the contents of the discourse pointer. The reader would be forced to search his memory to retrieve the relevant information. The duration of the search process should be reflected in the duration of the subject's response latency.

The subject was timed while he read each successive sentence of a paragraph on a video monitor and decided whether it was consistent or contradictory with the previous sentences. On a contradictory trial, a filler sentence contradicted one of the previous fillers (for example, in the paragraph above, the sentence in position 5 contradicts the sentence in position 3). The contradictory fillers never preceded the target. Each paragraph contained at least one contradictory sentence except in cases where the target occurred in the final position. The fillers, like the target, were cleft and pseudocleft sentences. Therefore, the superficial form of the sentences could not differentially cue the subject to the target sentence. Our subjects did not report discriminating between the various fillers and the target, nor did they guess the intent of the experiment.

The paragraphs were randomly assigned to the 32 different conditions, composed of three orthogonal factors: (1) the target sentence had an information structure that was congruent or incongruent with the opening sentence, (2) the target sentence was a cleft agent, cleft object, pseudocleft agent, or pseudocleft object; and (3) there were 0, 1, 2, or 3 filler sentences between the opening sentence and the target. The 12 subjects were college students.

Results. Subjects took less time to integrate the target sentence when its information was congruent with the opening sentence, as shown in Figure 2. Overall, sentences with a congruent structure were verified about 1.4 sec faster than sentences with an incongruent structure, F' (1,41) = 7.92, $p < .01$. (The F' statistic is used to test the reliability of this effect over populations of subjects and paragraphs). The information structure of the sentence being processed provides an important cue for relating the sentence to the preceding discourse. The reader uses the information that is marked as old to determine how the current sentence relates to some aspect of the discourse. When this old information matches what is designated by the discourse pointer, the integrative process is relatively fast. The congruence allows the reader to immediately proceed to add on the new information. By contrast, if the information marked as old in the currently processed sentence does not match the contents of the discourse pointer, the reader must search through his memory representation of the previous sentences. When the information structure is incongruent, the information marked as old does not match any of the propositions in the reader's memory. The sentence must be reinterpreted before it can be correctly integrated with the previous information. Consequently, the incongruent sentences have longer response latencies.

Insert Figure 2 about here

In cases where the target sentence immediately followed the opening sentence, this experiment resembles the previous one in which a sentence with a congruent or incongruent information structure followed a picture. In that experiment, the advantage of congruent sentences was 189 msec, considerably less than the 2.3 sec in the current experiment when there were no intervening fillers. One possible explanation for the difference in magnitude is that the sentences in the previous experiment varied only on specified dimensions from trial to trial. When an incongruent structure appeared, the subject may have known exactly how to reinterpret the sentence in order to integrate it with the previously presented picture. By contrast, the current experiment had many different sentences on many different topics. It would have been more difficult to find the relevant information in memory, and to formulate a translation from the incongruent structure to the congruent one. Thus, the added

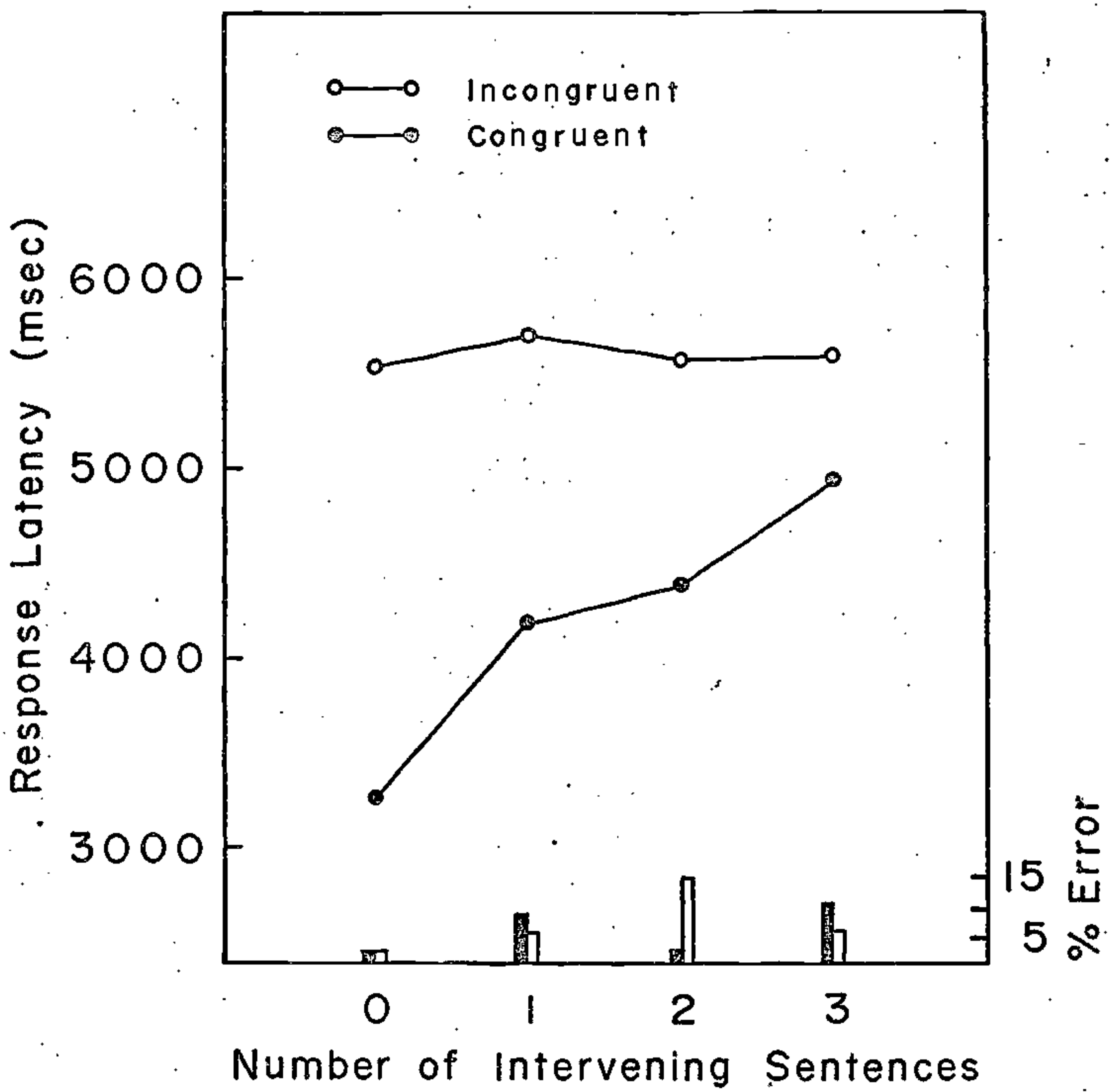


Figure 2. The mean response latencies for incongruent and congruent sentence structures as a function of the number of sentences intervening between the opening sentence and the target.

complexity of the paragraph task magnifies the effect of information structure on comprehension time.

It was expected that the response latency would increase with the number of fillers intervening between the opening sentence and the target. There was no such increase when the target had an incongruent information structure; since the latencies for incongruent sentences were highly variable, they must be interpreted with caution. However, when the information structure of the target was congruent with the opening sentence, latencies did increase with the number of intervening sentences, as shown in Figure 2. As more material intervenes between the initial sentence and the target, the reader must search through more stored information, taking more time. Another study, using a memory paradigm, provides converging evidence for this view. Subjects read a paragraph and then answered questions that required integration of information presented in separate sentences (Frase, 1973). The reader's ability to correctly integrate two items of information was facilitated if they occurred in adjacent sentences. But as the separation between the sentences to be integrated increased, the probability of a correct response decreased. One explanation for Frase's finding is that during the comprehension of a sentence in a paragraph, the search for relevant previous information is terminated after a criterion amount of time has passed. If the separation between sentences is large, the integration time may exceed the criterion. As a consequence the probability of integration decreases. Thus, whether or not the information from two sentences is integrated depends partially on how close they are to each other in the text.

The performance in our paragraph comprehension experiment provides the strongest evidence that the effect of the discourse pointer is more than just a general context effect. In all the experimental conditions, the relevant preceding information, the context, had been read and internalized by the reader. What determined the speed of response was the relation between the sentence being processed and the part of the context to which it referred. In other words, what is important is how the reader finds the relevant information among all the other context information.

The discourse pointer provides an index to relate the sentence being processed to a particular part of the context. If the discourse pointer designates what the sentence presupposes or marks as old, then the sentence is integrated quickly. The pointer designates the most current theme or topic of the discourse.

One issue we have not thoroughly explored is what determines the movement of the discourse pointer in the course of comprehending a paragraph. We have assumed that the opening sentence sets the pointer to its own content, and this is probably a good assumption. After the first sentence, there are a number of factors that could control the movement of the pointer. One operative device is an inter-sentential connective that explicitly denotes the relation between the sentence being processed and the previous context. A connective like <u>For example</u>, should move the pointer from its previous location to a new one, with the labelled relation "is an instance of". A phrase like <u>To return to the main point</u> should move the pointer to the structure that it had previously designated. We will return to the role of such connectives later in this chapter.

In a paragraph that is primarily narrative, the pointer might move from sentence to sentence, as they occur in the text. However, we have not formalized the rules that govern the movement of the pointer in such circumstances. As a first step, we have been content to assume that in our simple narrative paragraphs, the pointer does move from sentence to sentence. The results of the paragraph comprehension experiment validate some of our assumptions, by showing that rapid integration of a sentence with the preceding text depends not only on having the contextual information in memory, but also having an index to that information. When the index is up-to-date and congruent with the information structure of the incoming sentence, then that sentence is speedily integrated with the text.

Relating answers to questions

One instance where there is a well-defined relation between the discourse pointer and the subsequent sentence is in a question-answer couplet. When a question is asked, the discourse pointer specifies a particular relationship between the question and the expected answer. A good answer will provide the requested information and mark it as new. Consider the question-answer couplet: Who painted the barn? JOHN. The question set the discourse pointer to expect a particular kind of answer -- the identity of the person who painted the barn. John is an acceptable answer so the couplet is easily comprehended. The comprehension of a question-answer pair depends upon how the structure of the answer matches the content of the discourse pointer established by the preceding question. As an example, consider the following answers to the question Who painted the barn?

(1) The one who painted the barn was John.

(2) *What John painted was the barn.

Sentence (1) is an acceptable answer because the question requests the identity of someone and (1) provides that identity and marks it as new information. By contrast, (2) jars the reader because it marks <u>the barn</u> as though it were the request, new information. The mismatch between the question and the answer (2) interferes with comprehension. The answer (2) is not in itself a bad sentence. It would be an appropriate reply to the question <u>What did John paint?</u> These question-answer pairs demonstrate how the new information in the answer must conform to the structure established by the preceding question.

We designed an experiment to study the comprehension of a question-answer pair in which the answer's information structure was congruent or incongruent with the question. The experimental procedure required a subject to read a question, like <u>Where is John?</u>, and then a sentence, like <u>It is John who is leading Jim</u>, and use the information in that sentence to answer the question. The subject responded either "ahead" or "behind" to indicate John's relative position by pressing one of two buttons. The main variable of interest was whether the question probed information that was marked as new in the subsequent sentence or information that was marked as old. The response latency for answering a question should be shorter when the question proded the information marked as new.

Thirty-two different question-sentence pairs were constructed by using four kinds of sentences, cleft agent, cleft object, pseudocleft agent, and pseudocleft object, the predicates <u>leading</u> and <u>following</u>, the names <u>John</u> and <u>Jim</u>, and a question that probed either the name marked as new or the name that was part of the old information in the sentence. Each of 12 subjects ran through two blocks of 32 randomly ordered trials.

<u>Results.</u> Responses were considerably faster, by 284 msec, when

the question probed the new information in the sentence, $F\ (1,11) = 9.19$, $p < .01$. Thus, the main hypothesis was confirmed: performance was facilitated substantially when the information structure of the sentence corresponded to the question's request for information. The mean latencies and error rates for the various question-sentence pairs are shown in Table 3.

Insert Table 3 about here

The advantage of questions that probed the new information was present for seven of the eight sentences. The only exception was the pseudocleft object sentence with the verb leading (i. e., The one who John is leading is Jim), which had faster responses when the question probed the old information. This reversal occurred only for this sentence and only in Block 2, suggesting that it may be due to random fluctuation.

A question sets the discourse pointer to a proposition with a constitutent missing. For example, asking "Where is John" sets the pointer to (LOCATE, JOHN, ?). An easily comprehensible answer not only provides the requested information, but also marks it as new. In ordinary discourse, the information structure of sentences correspond not only to explicit questions, but also implicit ones (Halliday, 1967). At the extreme, the speaker may mark as new information whatever he believes his listener does not know.

Comparing a sentence to a picture

The previous experiments have demonstrated how the information structure of a sentence can influence the way the sentence is related to preceding information stored in memory. Can this information structure

Table 3

Mean Response Latency in msec and (% error)

in Question-Answer Experiment

Stimulus Sentence	Question Interrogates: New		Question Interrogates: Old	
Pseudocleft agent The one who is leading/following Jim is John.	3860	(6%)	4276	(9%)
Pseudocleft object The one who Jim is leading/following is John.	4071	(14%)	3952	(2%)
Cleft agent It is John who is leading/following Jim.	3282	(1%)	3745	(4%)
Cleft object It is John who Jim is leading/following.	3960	(2%)	4336	(18%)
	3793		4077	

also influence the way the sentence is related to perceptual events that follow? To examine this question, we designed an experiment in which subjects read a sentence describing the relative positions of two people, followed by a schematic array that depicted two people walking in a particular direction. The task was to verify if the sentence was true or false of the picture. An example of a true sentence and the accompanying picture is:

The one who is leading Dave is Jill.

Jill Dave
← ←

The array consisted of a woman's name, a man's name, and two arrows to indicate the direction in which each of them was walking. The woman in the array was always located on the left, and the man on the right, as shown. Thus, the subject always knew where to look for information corresponding to the new or old constituent. We were interested in whether the subjects would first check the information marked as new or the information marked as old in the sentence.

The main contrast we wanted to make concerned the cases when the picture falsified the information marked as new and those in which it falsified the information marked as old. An example of a display that falsified the new constituent would be:

The one who is leading Dave is Jill.

Sue Dave
← ←

An example of a display that falsified the linguistically old constituent would be:

The one who is leading Dave is Jill.

Jill Mike
← ←

Let us assume that the sentence-picture comparison proceeds roughly as follows. First, the name of one of the people mentioned in the sentence is compared to the name in the corresponding slot in the picture. If the names mismatch, the comparison can terminate, with a response of <u>false</u>. If the names match, then the other pair of names is compared. If they match, then the verb can be compared to the relation depicted in the picture. If the comparison process does terminate on a mismatch, then the response latencies can indicate the order in which constituents are compared. Specifically, mismatches on constituents compared first will yield shorter response latencies than mismatches on constituents compared second. Thus, the relative response latencies for the two kinds of false trials should indicate whether the information marked as old or new is compared first.

There were 48 distinct sentence-picture combinations, composed of the four types of sentences (cleft agent, cleft object, pseudocleft agent, and pseudocleft object), whether the new information referred to a male or a female, and 6 different pictures. Three of the pictures correctly depicted what was described in the sentence. The other three pictures falsified the sentence by mismatching the agent, the object, or the verb. Different pairs or triplets of names were used in the 48 trials. Twelve college students ran through three blocks of 48 trials.

<u>Results.</u> The main result was that latencies were shorter when there was a mismatch on the new information than when there was a mismatch on the old information. This result held for all four sentence types as shown in Table 4. The mean difference was 167 msec, $\underline{t}(11) = 2.90$, $p < .01$. This result suggests that people first compared the new information from the sentence to the appropriate part of the picture.

If there was a mismatch, then the comparison process terminated and there was a quick response. If the new information matched, then they went on to compare the old information. If it mismatched, then the comparison process terminated.

- - - - - - - - - - - - - -

Insert Table 4 about here

- - - - - - - - - - - - - -

In a follow-up study, we looked for an overt difference in the perceptually encoding of elements in the display, as a function of the sentential information structure. We designed an experiment very similar to the one above, except that the subject heard the sentence and we monitored his eye movements while he scanned the perceptual display. There was a significant tendency to look first at the part of the display that contained the element correspond;ng to the word marked as new. For example, when a female name was marked as new, the subject tended to first fixate on the part of the display that contained the female name. This result confirms the conclusion from the latency study, that new information is verified first.

These results are consistent with a study that used a very different methodology. Cleft and pseudocleft sentences like <u>The one who is petting the cat is the girl</u> were presented auditorily, and followed by a picture presented for only 50 msec (Hornby, 1974). The subject's task was to decide whether the sentence was an accurate description of the picture. The false pictures incorrectly depicted either the constituent marked as old or the constituent marked as new, as shown in Figure 3. Of key interest were the false cases that were erroneously labelled "true" by the subjects. Subjects made significantly fewer of these errors when

Table 4

Mean Response Latency and (% error)

in Sentence-Picture Verification Experiment

	Picture Falsifies	
Stimulus Sentence	New	Old
<u>Pseudocleft agent</u> The one who is leading/following Barb is John.	2917 (1%)	3180 (0%)
<u>Pseudocleft object</u> The one who Barb is leading/following is John.	3020 (0%)	3228 (0%)
<u>Cleft agent</u> It is John who is leading/following Barb.	2680 (0%)	2821 (0%)
<u>Cleft object</u> It is John who Barb is leading/following.	2880 (8%)	2933 (0%)
	2874	3041

the picture falsified the new information than when it falsified the old information. If the information marked as new were verified first, then the representation of the picture would still be fresh during verification, and verification accuracy would be high. This representation would decay with time, so that when the subject subsequently verified the old information, his accuracy would decline.

- - - - - - - - - - - - - -

Insert Figure 3 about here

- - - - - - - - - - - - - -

The order in which the constituents are verified in all these studies may be explained by considering the normal communicative function of the old-new distinction. When information is marked as old, it is a signal to the reader that he already has identical or very closely related information stored in memory. Normally, he should not have to check whether it is true of the perceptual environment. By contrast, when information is marked as new, it is a signal to the reader that he has not yet heard this particular bit of news. Thus, it might well be subjected to a validity check before being integrated into memory. Thus evidence pertaining to information marked as new is verified before evidence pertaining to information marked as old.

Using the discourse pointer in writing

Stylists and writing teachers have evolved certain guidelines for writing good prose by analyzing examples of good and bad writing and by relying on their own trained introspections. These rules are often compiled in books with titles such as "The Art of Readable Writing" or "How to Speak, Write, and Think More Effectively." The rules concern the kinds of words or sentences that a writer should use, as well as more

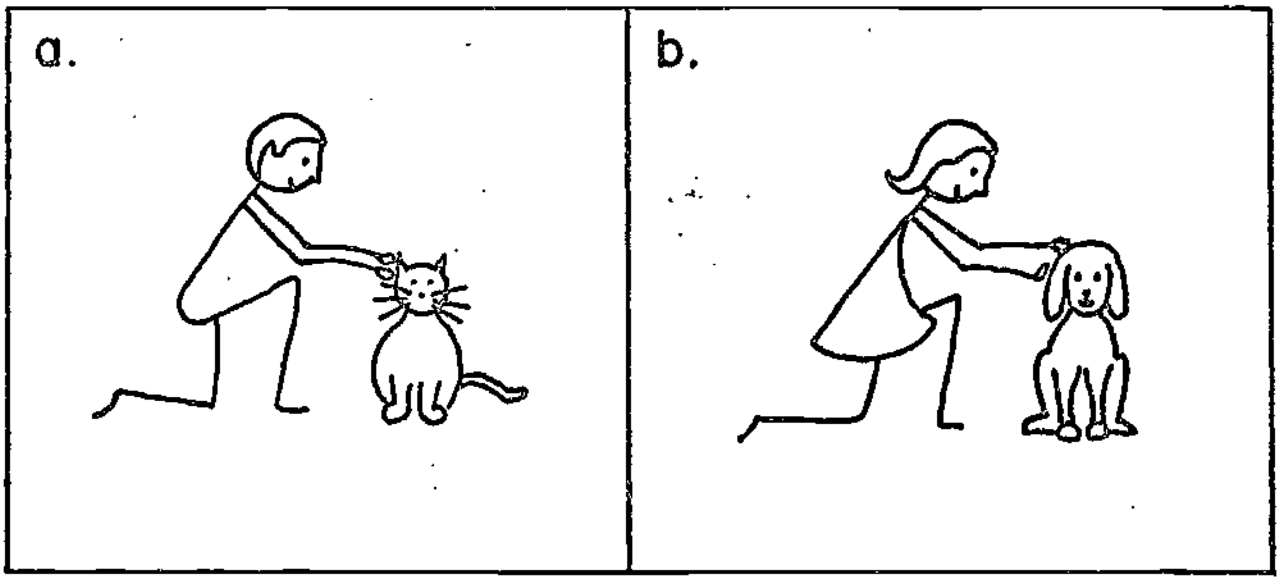


Figure 3. Two pictures that might follow a sentence like The one who is petting the cat is the girl. Picture (a) falsifies the new information in the sentence. Picture (b) falsifies the old information.

global guidelines for organizing various kinds of prose. In this section, we will be concerned primarily with rules for making sentences fit together. We will show that these rules tend to generate prose that facilitates the reader's comprehension.

<u>The serial order of old and new information</u>

The processing distinction between old and new information that we have examined has also been discussed by writing teachers. In particular, they have been concerned with the serial order in which the old and new components occur. One standard guideline is to place the new information at the end of a sentence. For example, Strunk and White (1959) advise writers to "place the emphatic words of a sentence at the end."

> The proper place in the sentence for the word or group of words that the writer desires to make most prominent is usually at the end. The word or group of words entitled to this position of prominence is usually the logical predicate, that is, the <u>new</u> element in the sentence..... (Strunk & White, 1959, pp. 26)

Similarly, Flesch (1946) advises writers to "Go from the rule to the exception, from the familiar to the new." The implicit psychological assumption is that the old information will establish a framework. Establishing this framework is equivalent to setting the discourse pointer to a particular concept before presenting the new information. After the pointer has been set, it is easier to integrate the new information with the previous context.

In sentences that do not have an explicit marking of the old and new information, the information at the end of the sentence is usually assumed to be new (Halliday, 1967). For example, in a simple active, transitive sentence such as John loves Mary, the fact that John loves someone is interpreted as old information and the identity of that someone, Mary, is interpreted as new. Of course, the context can change this. For example, in response to Who loves Mary? it is appropriate to say John loves Mary. But in the absence of any other context, the last part of the sentence tends to be interpreted as new information.

The judgments of naive subjects tend to corroborate Halliday's linguistic analysis of active and passive sentences (Hornby, 1972). When subjects were asked to judge what active sentences were about (that is, what the old information was), 62% of the subjects said that the sentence was about the agent. For passives, 65% of the subjects said that the sentence was about the recipient. In both these cases, the constituent at the beginning of the sentence was judged to be the old information, and by default the constituent at the end was judged as new. In sentences like clefts and pseudoclefts, which explicitly mark the old-new distinction, the agreement between the subjects' judgments and the linguistic analysis was even higher. But in sentences which don't explicitly mark the distinction, about two thirds of the subjects interpreted the element at the end of a sentence as the new one.

One literary device, "dovetailing", makes use of the old-new structure to integrate two successive sentences. Two sentences are dovetailed if the beginning of the second sentence has the same referent as the end of the first sentence (Eastman, 1970). Consider the following two dovetailed sentences:

> What we must never neglect is the will to win. The determination to survive can extend a man's resources.

The new information in the first sentence emphasizes "the will to win" and the discourse pointer is set to the proposition that the will to win is important. Then the second sentence refers to this proposition at the very beginning with the words "the determination to survive" and adds the new information "...can extend a man's resources." The same two sentences are less comprehensible when they are not dovetailed:

> What we must never neglect is the will to win. A man's resources can be extended by the determination to survive.

In this case, the passive sentence signals that "a man's resources" should be old information, but there has been no mention of this concept and so the discourse pointer does not index it. Consequently the reader must temporarily store that element until the pragmatically old information is introduced at the end of the sentence. Dovetailing is an effective writing device because it uses the information structure of the sentences being combined to optimize the integrative processes in comprehension.

Guidelines for writing may suggest placing the new information at the end of a sentence, but do good writers take this advice? An essay by Bertrand Russell, "The Elements of Ethics" has been analyzed in terms of the information structure of the sentences (Smith, 1971). The sentences in this essay are quite long and generally complex. However, Russell consistently constructed the sentences so that the most important information unit, the new information, occurred in the final position. Of the sentences Smith was able to classify, 86% had the new information at the end. The analysis of Russell's essay indicates that effective communication of complex ideas is mediated by a prose style that facilitates comprehension. Moreover, it shows that literary analysis need not remain the exclusive domain of the artist, but can be opened to a science of literary aesthetics based on psycholinguistic processes.

Repetition of key words

Another device that facilitates the integration of ideas from different sentences is the repetition of a key word or concept. In fact, recent experiments indicate that it is easier to comprehend a paragraph that has several references to a restricted number of concepts than one that introduces many new, different concepts (Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975). An example of a passage that contained many repetitions and a small number of different concepts is:

> The Greeks loved beautiful art. When the Romans conquered the Greeks, they copied them, and, thus learned to create beautiful art.

Notice that the passage has two repetitions of "the Greeks", two repetitions of "beautiful art" and two instances of pronominalization. The reading time for this kind of passage was compared to a passage with approximately the same number of words, but which had few pronominal referents or repetitions, for example:

> The Babylonians built a beautiful garden on a hill. They planted lovely flowers, constructed fountains and designed a pavilion for the queen's pleasure.

This passage has no repetition of key words and only one instance of a pronominal referent, and refers to many different concepts.

The passages with repetitions and pronominal reference took less time to read than the passages without repetitions. Moreover, subjects also remembered the passages with repetitions better, perhaps because the repetition resulted in a more integrated memory structure. Kintsch and his colleagues also point out that a passage with many repetitions has a relatively small amount of new information in each sentence and instead has more familiar, old elements. Kintsch and his colleagues suggest that it is easier to process propositions that build upon from old information, rather than ones that continually introduce new concepts. "Propositions that contain new concepts require an additional processing step on the part of the reader. Not only must a proposition itself be inferred from the text, but the new concept apparently requires some special processing in that it must be encoded. Old concepts, on the other hand, need not be re-encoded. A reference to the already encoded representation is sufficient, in this case." This research demonstrates how repeated reference to a central concept affects the way sentences are integrated during comprehension. Not surprisingly, writing stylists have suggested that "the repetition of the key word or synonyms of those words will build the coherence of a passage" (Eastman, 1970, p. 217).

<u>Intersentential connectives</u>

Another device that establishes the relationship between sentences are the intersentential connectives, such as <u>therefore</u>, <u>because</u>, <u>however</u>, <u>on the other hand</u>. Consider the following paragraph:

> Edgar wanted to go into forestry. Granted the hours were long and the pay was low. Nevertheless he wanted to become a forest ranger.

This paragraph flows relatively smoothly from sentence to sentence primarily because of the information provided by the intersentential connectives. The first sentence sets the discourse pointer to the propositions stating that Edgar wanted to go into forestry. Then the connective granted indicates that the second sentence will provide an opposing argument. Without this connective, the second sentence would appear to present a supporting argument, which is contrary to our notion that long hours and low pay are negative attributes of a job. So the connective indicates how the second sentence is related to the proposition designated by the discourse pointer. Similarly, the connective nevertheless indicates that the third sentence will return to the original line of argument. In general, the connectives indicate the relation between the proposition designated by the pointer and the current sentence.

Connectives can be classified in terms of the inter-sentence relations they denote. The list below (adapted from Brooks & Warren, 1970; Eastman, 1970) provides a representative analysis of connectives.

To show that the same topic continues: this, that, these, such, the same.

To introduce another item in the same series: another, again, a second (third, etc.), further, furthermore, moreover, similarly, likewise, too, finally, also.

To introduce another item in a time series: next, then, later on, afterwards, finally.

To introduce an example or illustration of what has been said: for instance, for example, specifically.

To introduce a consequence of what has just been said: accordingly, thus, therefore, then, as a result, hence, consequently, so.

To introduce a restatement of what has just been said: in other words, to put it differently, that is to say.

To introduce a concluding item or summary: finally, altogether, all in all, the point is, in conclusion, to summarize.

To introduce material which opposes what has just been said: but, however, on the other hand, on the contrary.

To introduce a concession to an opposing view: to be sure, undoubtedly, granted, of course.

To show that the original line of argument is resuming after a concession: still, nevertheless, nonetheless, all the same, even though.

Intersentential connectives relate the sentences of a paragraph to each other much as verbs relate the constituents of a sentence. In cases where the connective does not appear in the text, the reader must infer the relation between the sentences by drawing on his knowledge of the referential situation. The integrative process should be shorter in duration when connectives do appear and thus make the inference process unnecessary.

Anaphoric reference

Anaphoric reference is a device that allows a writer to refer back to a previously mentioned concept by appealing to the previous mention. For example, in the sentences, Edgar certainly loves cars. He dotes on his '56 Chevy, he in the second sentence refers back to Edgar. The two sentences are integratable because the referent of the pronoun in the second sentence is designated by the discourse pointer at the time the second sentence is being processed. By contrast, consider a different version of the sentences: Edgar certainly loves cars. Joyce hates them. He dotes on his '56 Chevy. The reader might have some difficulty in comprehending the referent of he in the third sentence, even though it is logically unambiguous. The reason for the difficulty is that after the second sentence, the discourse pointer is set to the proposition that Joyce hates cars. The he in the third sentence does not refer to Joyce, so the reader is forced to search for the appropriate referent elsewhere. This example indicates how anaphoric reference interacts with the discourse pointer. We will consider this interaction in more detail for two kinds of anaphoric reference, pronominalization and definite description.

The use of a pronoun to denote a concept presupposes that the concept is known to the listener. The referent may have been communicated in the preceding discourse, as in the example of Edgar and the car, or the referent may be obvious from the conceptual context, e. g., Look out! It's falling! Pronominalization requires that the listener search his representation of the text for the referent of the pronoun. The search will start at the contents of the discourse pointer.

A recent study externalized some of the search processes in comprehension triggered by pronouns in a text (Cooper, 1974). The subjects in this experiment listened to a passage, for example, one passage concerned a trip to Africa, mentioning a dog, a zebra, a group of peacocks, etc. At the same time, subjects were looking at a set of pictures that included these objects. As one might expect, subjects tended to look at the picture of the object that was being mentioned. Subjects also tended to fixate the referential picture when a pronoun occurred. Looking at the appropriate picture presumably correlates with the memory search for the referent of the pronoun.

When two sentences are linguistically related by pronominal reference, then they tend to be comprehended and remembered together. In one interesting demonstration of this phenomenon (Lesgold, 1972), subjects listened to compound sentences whose clauses were linked by the conjunction and or by pronominal reference. For example, a sentence conjoined with and was:

> The blacksmith was skilled and the anvil was dented
> and the blacksmith pounded the anvil.

The same sentence with a pronominal reference was:

The blacksmith was skilled and he pounded the anvil which was dented.

After listening to a series of such sentences, the subjects were given prompt words and were asked to recall the gist of the sentences. Recall was better in two ways when the sentence had pronominal reference than when it was conjoined with <u>and</u>. First, subjects recalled more words from the pronominal sentences. Second, they recalled more words of the clause that <u>didn't</u> contain the prompt word. This latter result is important because it suggests that the information from the two clauses was more likely to be integrated in memory when a pronominal referent linked them.

The definite article <u>the</u> is another type of anaphoric reference, one that can indicate that the modified noun has been referred to in the preceding context. By contrast, the indefinite article <u>a</u> often modifies a noun whose referent is new (cf., Karttunen, 1971). The role of the article is especially important within discourse, since choice of definite or indefinite article may signal whether two nouns are co-referential. For example, the sentences <u>Yesterday, Lou sold her Chevy. Today, Glen bought the car</u> imply that the same car entered into both transactions. The sentences would have a very different meaning if the indefinite article <u>a</u> replaced <u>the</u>: <u>Yesterday, Lou sold her Chevy. Today, Glen bought a car</u>. Hence, the definite or indefinite articles tell the listener how to integrate the two clauses.

The indefinite article, like a pronoun, assumes that the referent exists. As an example, consider the following sentences from Karttunen (1971):

(1) a. Bill has a car. b. It is black.

c. The car is black.

Either (1b) or (1c) could plausibly follow (1a). However, consider the sequence:

(2) a. Bill doesn't have a car. b. *It is black.

c. *The car is black.

Neither (2b) nor (2c) can follow (2a) because they presuppose the existence of a car that does not exist. When such existential presuppositions are violated comprehension takes longer (Haviland & Clark, 1974). Subjects read pairs of sentences like those below and pressed a button to indicate when they had understood the second sentence:

(3) a. We got some beer out of the trunk.

b. The beer was warm.

(4) a. Andrew was especially fond of beer.

b. The beer was warm.

The definite article in 3b and 4b presupposes the existence of some particular beer. Sentence 3a establishes the existence of some particular beer (namely the beer that was taken from the trunk), but 4a does not. As predicted, subjects had longer comprehension times for 4b and 3b. The difference in comprehension times demonstrates that the reader tries to relate the meaning of the second sentence to the representation established by the prior sentence.

Inappropriate anaphoric reference can also disrupt the comprehension of larger units of text, such as passages. Presenting the sentences of a passage in a scrambled order disrupts shadowing performance to a greater degree if the passage contains more anaphoric reference (Rosenberg & Lambert, 1974). In other words, the more closely the original sentences were related the more disruptive was the violation of the passage structure. The results show that even in a shadowing task, people use anaphoric reference as a cue to comprehension; the violation of the passage structure makes the cue misleading.

Much like pronouns, definite articles encourage people to integrate sentences in comprehension and in memory. This integrative behavior was examined in a study in which subjects read a list of 17 sentences that could form a coherent passage (DeVilliers, 1974). However, the subjects were not told that the sentences could be related to each other. The sentences contained indefinite or definite articles. The following sentences are excerpted from the sequence of sentences with indefinite articles:

> A man bought a dog.
> A child wanted an animal.
> A father drove to his house.
> A cottage stood near a park.
> A boy was delighted with a gift.
> A twosome went exploring along
>   a path into a woods.

When the indefinite articles are replaced with definite articles, the same sequence of sentences seems to form a story.

> A man bought a dog.
> The child wanted the animal.
> The father drove to his house.
> The cottage stood near the park.
> The boy was delighted with the gift.
> The twosome went exploring along
>   the path into the woods.

In both conditions, the sentences were presented one at a time in a memory drum. About half of the subjects in the definite article condition reported that the sentences seemed to form a story. These subjects recalled more sentences and had more inter-sentence lexical substitutions (for example, substituting dog for animal in recalling the second sentence). By contrast, the subjects in the indefinite article condition did not think that the sentences formed a story. Their recall was poorer and they did ıat make co-referential substitution errors. The definite articles increase the probability that readers will integrate the sentences, and when they do integrate them, then recall is improved.

Summary

We have reviewed a number of linguistic devices that can facilitate comprehension processes. Devices such as dovetailing, repetition of key words, and intersentential connectives set the discourse pointer so that the reader is prepared to integrate the next clause or sentence. This approach suggests that"good" writing may optimize the reader's comprehension processes. However, not all good literature is written to be optimally comprehensible. For example, stream-of-consciousness writing is not meant to facilitate comprehension, but rather to induce a sense of confusion. While our approach is not appropriate for all writing and comprehension tasks, it is applicable in the many cases where the primary goal is efficient communication of information.

At the beginning of this chapter, we argued that understanding what someone is talking about involves more than just deriving a representation of a sentence. Comprehension also involves relating the words and clauses in a sentence to other sources of information, such as the previous discourse or the perceptual context of the discourse. The various linguistic devices we have discussed provide cues to integrating a sentence with extra-sentential information. The integrative processes influence the speed with which we understand sentences in context and the accuracy with which we later remember them.

REFERENCES

Brooks, C., & Warren, R. P. Modern Rhetoric. New York: Harcourt, Brace & World. Third edition, 1970.

Chafe, W. L. Meaning and the Structure of Language. Chicago & London: University of Chicago Press, 1970.

Cooper, R. M. The control of eye fixation by the meaning of spoken language. Cognitive Psychology, 1974, 6, 84-107.

de Villiers, P. A. Imagery and theme in recall of connected discourse. Journal of Experimental Psychology, 1974, 103, 263-268.

Eastman, R. M. Style. New York: Oxford University Press, 1970.

Fillenbaum, S. Syntactic factors in memory. Janua Linguarum, Series Minor, the Hague: Mouton, 1973.

Flesch, R. How to Write, Speak, and Think More Effectively. New York: Harper & Brothers, 1946.

Frase, L. T. Integration of written text. Journal of Educational Psychology, 1973, 65, 252-261.

Halliday, M. A. K. Notes on transitivity and theme in English: II. Journal of Linguistics, 1967, 3, 199-244.

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.

Hornby, P. A. Surface structure and presupposition. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 530-538.

Karttunen, L. Discourse referents. Indiana University Linguistics Club manuscript, 1971.

Kintsch, W., Kozminsky, E., Streby, W. J., McKoon, G., & Keenan, J. M. Comprehension and recall of text as a function of content variables.

Journal of Verbal Learning and Verbal Behavior, 1975, 14, 196-214.

Lesgold, A. M. Pronominalization: A device for unifying sentences in memory. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 316-323.

Rosenberg, S., & Lambert, W. E. Contextual constraints and the perception of speech. Journal of Experimental Psychology, 1974, 102, 178-180.

Smith, C. S. Sentences in discourse: an analysis of a discourse by Bertrand Russell. Journal of Linguistics, 1971, 7, 213-235.

Strunk, W., & White, E. B. The Elements of Style. New York: The MacMillan Co., 1959.

Footnote

[1]The order of authors is arbitrary. This paper represents a collaborative effort. The project was supported in part by the National Institute of Education, Grant NIE-G-74-0016 and by the National Institute of Mental Health, Grant MH-07722, U. S. Department of Health, Education and Welfare.

CHAPTER IV

LINGUISTIC INFLUENCES ON PICTURE SCANNING[1]

Patricia A. Carpenter

and

Marcel Adam Just

Psychology Department

Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

To appear in J. Senders and R. Monty (Eds.)

Eye Movements and Psychological Processes

Several people at this conference have discussed how people scan linguistic material while they are reading. The next research question that we might ask is: What do people do with that material once they have read it? Part of the answer is that they form an internal representation of the information that was just read. And, that is the topic of central concern here: How is semantic information internally represented; What do the representations look like; And, how are those representations manipulated? In particular, I will discuss some research that has focused on the semantic structure of negation: How are negatives internally represented and how are those structures manipulated?

I am going to cover three main topics. First, I will explain the basic paradigm that we've used to investigate how people read and process negative sentences. In these tasks, a subject reads a sentence and then decides if it is true or false of an accompanying picture. Second, I will describe a model we've developed that accounts for the response latencies in these tasks (Carpenter and Just, 1975; Just and Carpenter, 1975). And then third, I am going to present data that show eye fixations are a valuable technique in discovering how people represent and process semantic structures.

[1]This paper represents a collaborative effort and order of authors is arbitrary. The project presented herein was performed pursuant to a grant from the National Institute of Education, Department of Health, Education, and Welfare, Grant NIE-G-74-0016. However, the opinions expressed herein do not necessarily reflect the position of policy of the National Institute of Education, and no official endorsement by the National Institute of Education should be inferred. The research was also partially supported by the National Institute of Mental Health, Grant MH-07722.

In the experimental situation, the subject reads a linguistic stimulus, a phrase or a sentence, and then compares it to a picture to decide whether or not they agree. Or alternatively, the subject may be asked to read a question and then scan an accompanying picture for information to answer the question. And we vary the semantic structure of the particular sentence or question to study the processing of different constructions.

Insert Table 1 about here

In one particular study that was typical of many others, the subject was shown an affirmative sentence like The dots are red or a negative sentence like The dots aren't red. Then he was shown a picture containing a group of red dots or a group of black dots, as shown in Table 1. And we timed the subject while he read the sentence, looked at the picture, and decided whether the sentence was true or false. The main dependent variable was how long it took to respond true or false.

Insert Figure 1 about here

The data from this experiment are shown in Figure 1 (the data are from Just and Carpenter, Expt II, 1971). There are two main results. First, there is an interaction between affirmation-negation and true-false. Affirmative sentences are easier to verify when they are true, but negative sentences are easier when they are false. The second result is that negative sentences take longer to verify than affirmative sentences. These results can be described in terms of two parameters: (1) falsification time, which is the absolute difference between the true and false for the affirmatives averaged with the absolute difference

TABLE 1

Representations and predictions for the four information conditions[a]

	True Affirmative	False Affirmative
Sentence:	The dots are red.	The dots are red.
Picture:	Red dots	Black dots
Sentence Representation:	(AFF, (RED, DOTS))	(AFF, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	+ +	index = false -
	response = true	+ +
	k comparisons	response = false
		k + 1 comparisons

	False Negative	True Negative
Sentence:	The dots aren't red.	The dots aren't red.
Picture:	Red dots	Black dots
Sentence Representation:	(NEG, (RED, DOTS))	(NEG, (RED, DOTS))
Picture Representation:	(RED, DOTS)	(BLACK, DOTS)
	index = false - +	index = false -
	+ +	index = true - +
	response = false	+ +
	k + 2 comparisons	response = true
		k + 3 comparisons

[a]Plus and minus signs denote matches and mismatches of the corresponding constituents. Each horizontal line of plus and minus signs indicates a re-initialization of the comparison process.

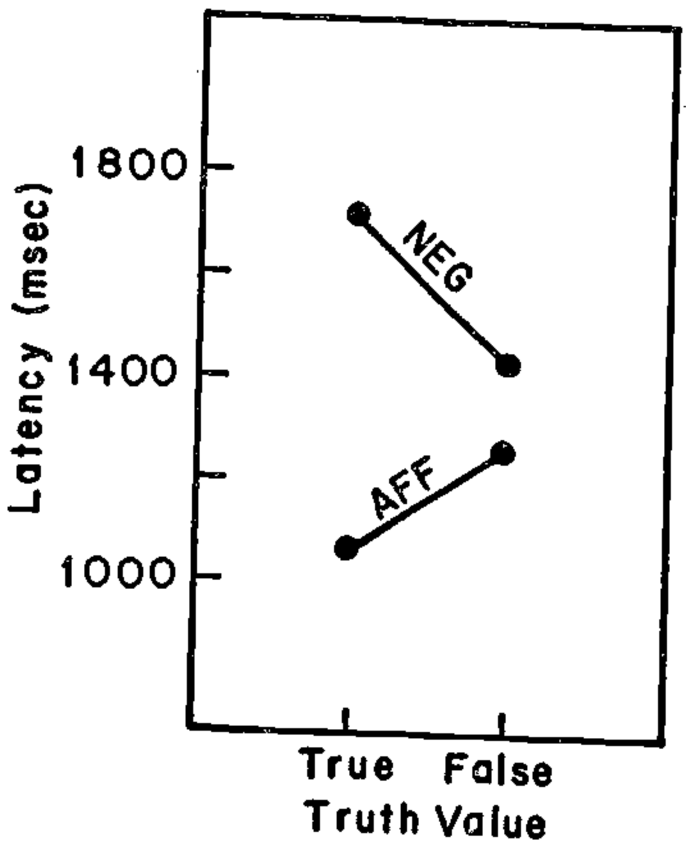


Figure 1. Results from a typical verification experiment (data from Just and Carpenter, Expt II, 1971).

for the negatives, and (2) negation time, the difference between affirmatives and negatives.

One of the first investigators to obtain these results, Gough (1965, 1966), suggested the basis of an explanation for what is going on in this task. He proposed that the information from the sentence and picture is represented and then compared. And the comparison process is easier when the color represented from the sentence matches the color represented from the picture. For example, affirmative sentences are easier when they are true because the color represented from the sentence matches the color that is encoded from the picture, e.g., The dots are red paired with a picture of red dots. Similarly, the color in a negative sentence like The dots aren't red matches the picture in the false case (a picture of red dots), but not in the true case (a picture of black dots). In summary, mismatches between color predicates make processing harder.

The overall difference in latencies for affirmative and negative sentences has been explained in very similar terms (Trabasso, et al. 1971; Chase and Clark, 1972; Clark and Chase, 1972). The explanation is that the negative sentence is represented as an affirmative core with an embedding negation marker. But pictures are represented affirmatively. So, when the information from a negative sentence is compared to the information in the picture, there is a mismatch between the negative polarity marker in the sentence and the representation of the picture. Again, this kind of mismatch makes the processing take longer.

Now, I will describe a model that explains why mismatches are harder to process. First, the information in the sentence and picture is represented in an abstract structure. The representation of a sentence like The dots are red must have several meaning components. The sentence concerns dots, it predicates that they are red, and furthermore, the predication is affirmative. The notation we will use to express these elements is a predicate-argument notation, (AFF, (RED, DOTS)), or for a negative sentence (NEG, (RED, DOTS)), as shown in Table 1. Similarly, when we then look at the picture we encode something about the dots, in one case that they are red, (RED, DOTS), or in the other case, that they are black (BLACK, DOTS). (Even though the affirmation marker isn't explicitly noted, the picture representations are assumed to be affirmative). According to the model, the latency differences among the four conditions in Figure 1 are due to the different amounts of time needed to compare the sentence and picture representations. The latencies are longer when corresponding constituents mismatch. The interesting question is to determine what extra mental operations underlie the longer latencies.

Insert Figure 2 about here

Figure 2 gives a model of what might be going on when people are comparing sentences and pictures. First of all, there is some sort of response index that has two possible states, true and false. This index is used to record mismatches in the comparison stage. Its initial state is true, but each mismatch causes a change of its state. Next, there is a stage where the sentence and picture are represented. Finally, the heart of the model is the comparison process in which each pair of constituents from the sentence and picture are retrieved and compared.

In the true affirmative case, the model says that you go through

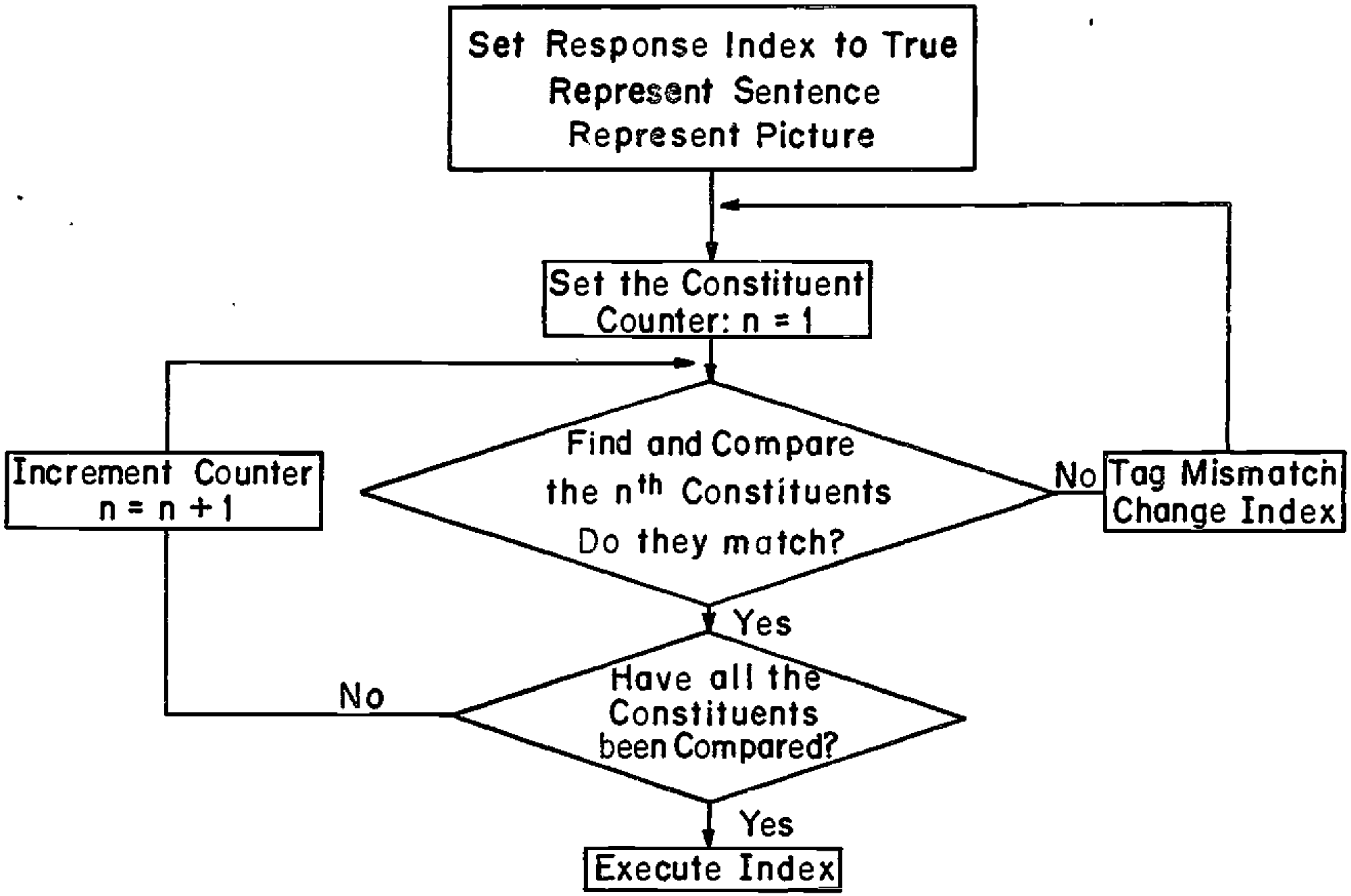


Figure 2. A model of the processes in verification.

comparing constituent by constituent starting with the inner proposition. The inner constituents match and since both the sentence and picture are affirmative, the polarities also match. Thus, there are no mismatches and no extra operations. Therefore, the time for a true affirmative represents the base time it takes to represent the sentence and picture and compare matching constituents.

When there is a mismatch, there are extra operations that increase the latency. A mismatch causes the comparison process to begin again with the inner constituents. For example, in the false affirmative case, the sentence says <u>The dots are red</u> but the picture shows black dots. The inner constituents mismatch and this has several consequences, that are detailed in Table 2. (A plus under two constituents denotes a match; a minus denotes a mismatch). The mismatch causes a change in the response index, from true to false. Also, the two constituents are tagged so they won't mismatch on future comparisons. Then, the inner constituents are recompared. And finally, the polarities are compared, and found to match. So this condition involves one more comparison operation than the true affirmative condition. A false negative has two more comparison operations than the true affirmative because of the mismatch between polarity markers. And a true negative has three extra comparisons because of mismatches between both the inner constituents and the polarity markers.

Insert Table 2 about here

Table 1 derives the predictions of this model for the four conditions. The model postulates a linear increase in the number of comparison operations, from true affirmatives to false affirmatives to false negatives

TABLE 2

A trace of the operations in verifying a false affirmative

Stimulus sentence: The dots are red.

Stimulus picture: A set of black dots

Operations	
Initialize response index to true	
Represent sentence:	(AFF, (RED, DOTS))
Represent picture:	(BLACK, DOTS)
1. Compare first constituents	-
Tag sentence constituent	(AFF, (M))
Tag picture constituent:	(M)
Change index to false	
Re-initialize comparison process	
2. Compare first constituents	+
3. Compare second constituents	+
Respond with content of index:	False
Number of comparisons:	k + 1, where k = 2

to true negatives. If the response latency is a direct function of the number of comparison operations, there should be a corresponding linear increase in latencies in the four conditions.

Insert Figure 3 about here

Figure 3 shows the exact same results as in Figure 1, but now plotted a different way. The X-axis represents the number of comparisons hypothesized for the four conditions. As predicted, the latencies show a linear increase. In fact, we have found this linearity in a large number of studies (summarized in Carpenter and Just, 1975). This supports the idea that there is an iterative "find and compare" operation and that mismatches cause re-initialization of the comparison process and consequently, extra operations.

This model can explain the processing of explicit negatives--sentences with the _not_ morpheme. In the next set of experiments, we used this paradigm and theory to investigate how implicit syntactic negatives are processed. A syntactically negative phrase can be identified by using what linguists call "co-occurrence rules." An example of such a rule is that negative clauses can _co-occur_ with _either_ (Klima, 1964). For example, it's okay to say _Mary didn't go and John didn't go, either_; but you can't say _Mary went and John went, either_. Normally, you would say _too_, rather than _either_. Since, _either_ only co-occurs with negatives, it signals the presence of a negative; it acts as a sort of litmus test. This co-occurrence rule suggests that words like _few_, _hardly any_ and _seldom_ are negative because phrases with these quantifiers can be "either-conjoined." For example, _Hardly any boys went; hardly any girls went, either_, is an acceptable sentence. There are other quantifiers

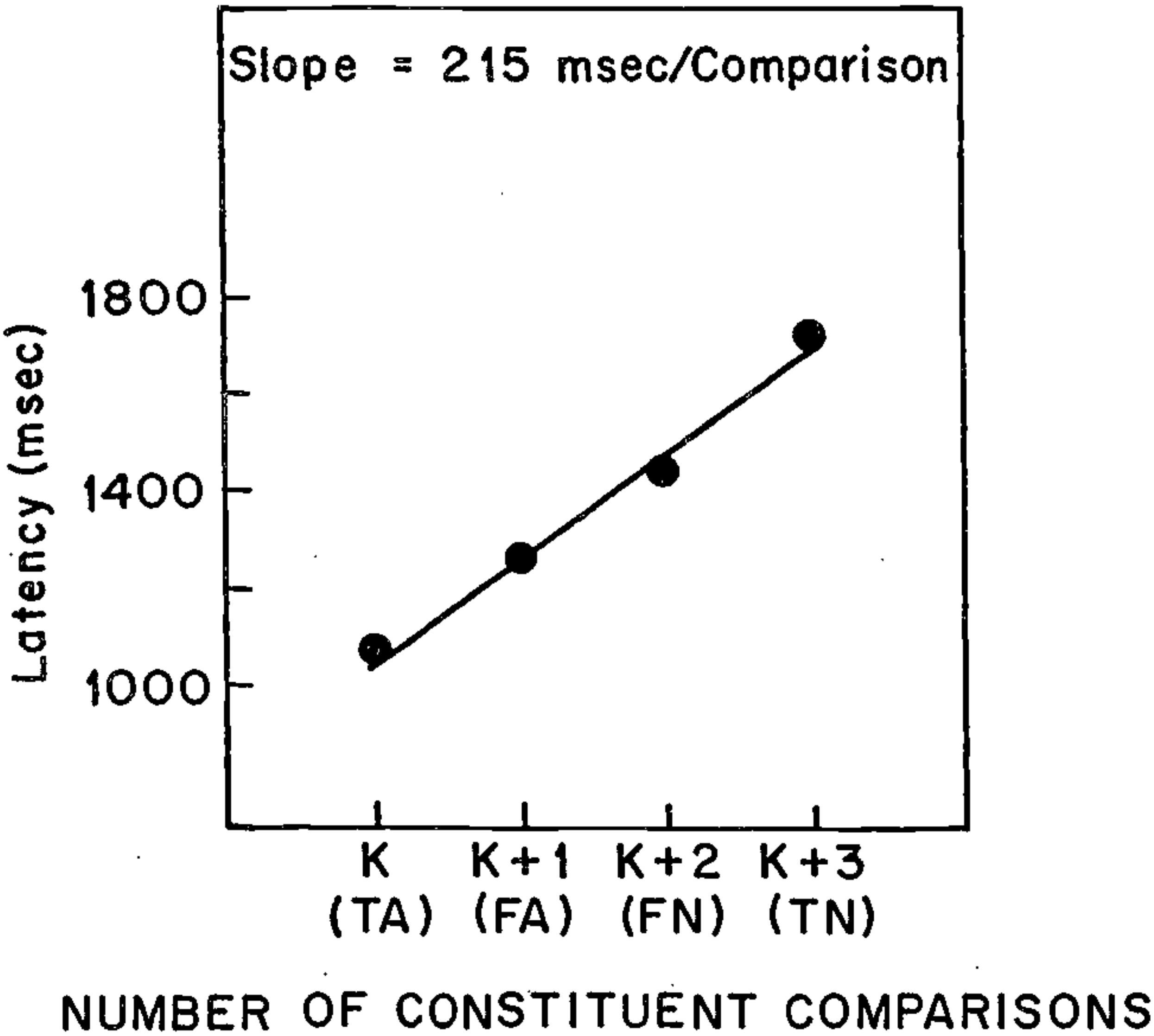


Figure 3. Results from the verification experiment plotted according to the hypothesized number of operations (data from Just and Carpenter, Expt II, 1971).

that can't be "either-conjoined." For example, it's not acceptable to say A minority of the boys went and a minority of the girls went, either.

The linguist has presented some interesting co-occurrence rules pointing out a contrast between words like hardly any and those like a minority. Now psychologists can ask what are the processing implications of this linguistic distinction? Are sentences with hardly any or few processed differently from those with a minority? The verification paradigm and the model allow us to determine how such sentences are internally represented and processed.

The experiment we ran to examine this question was a verification task where we presented our subjects with one of three kinds of quantified sentences. One kind of sentence had quantifiers like few, which the linguist would call syntactically negative. The psychological question is whether few is processed like a negative. A second kind of quantifier like many and most, was affirmative and referred to a large subset. Notice that according to the co-occurrence rule they are affirmative, since you can't say Many of the boys went; many of the girls went, either. The third type of quantifier refers to a small subset, like a minority or a small proportion. These are also affirmative by the linguistic co-occurrence rule; you can't say A minority of the boys went and a minority of the girls went, either. In the experiment (Just and Carpenter, 1971), the subject read a sentence like Many of the dots are red. The display showed a large subset of dots of one color and two exceptions. For example, the large subset could be fourteen red dots and the small subset would be two black dots, or vice versa. The predictions can be derived by considering how the sentences are represented. The sentence Many of the dots are red presumably is internally represented represented as an affirmative. So just like the affirmatives discussed before, the true case should be easier than the false case. However, Few of the dots are red may be represented and processed like a negative. If it is, the false case should be easier than the true case.

Insert Figure 4 about here

The results in Figure 4 show that our hypothesis was confirmed: many is processed like an affirmative, while few is processed like a negative. The results for quantifiers like few can be contrasted with the results for quantifiers like a minority. Sentences with quantifiers like a minority were easier when they were true, supporting our hypothesis that such quantifiers are represented as affirmations about the smaller subset.

At this point, eye fixations provide a converging operation to further study the way these structures are represented and processed. In the first experiment, we investigated whether the locus of fixation would reflect on how these implicit negatives are represented. We set up a situation where we could monitor how the subject fixated the picture after reading the sentence (Carpenter and Just, 1972). If few is internally represented as a negation of many, a subject might subsequently fixate the larger subset. In contrast, if a minority is represented as an affirmative quantifier about the smaller subset, a subject should look at the smaller subset. By analogous reasoning, a sentence with many might cause the subject to look at the larger subset.

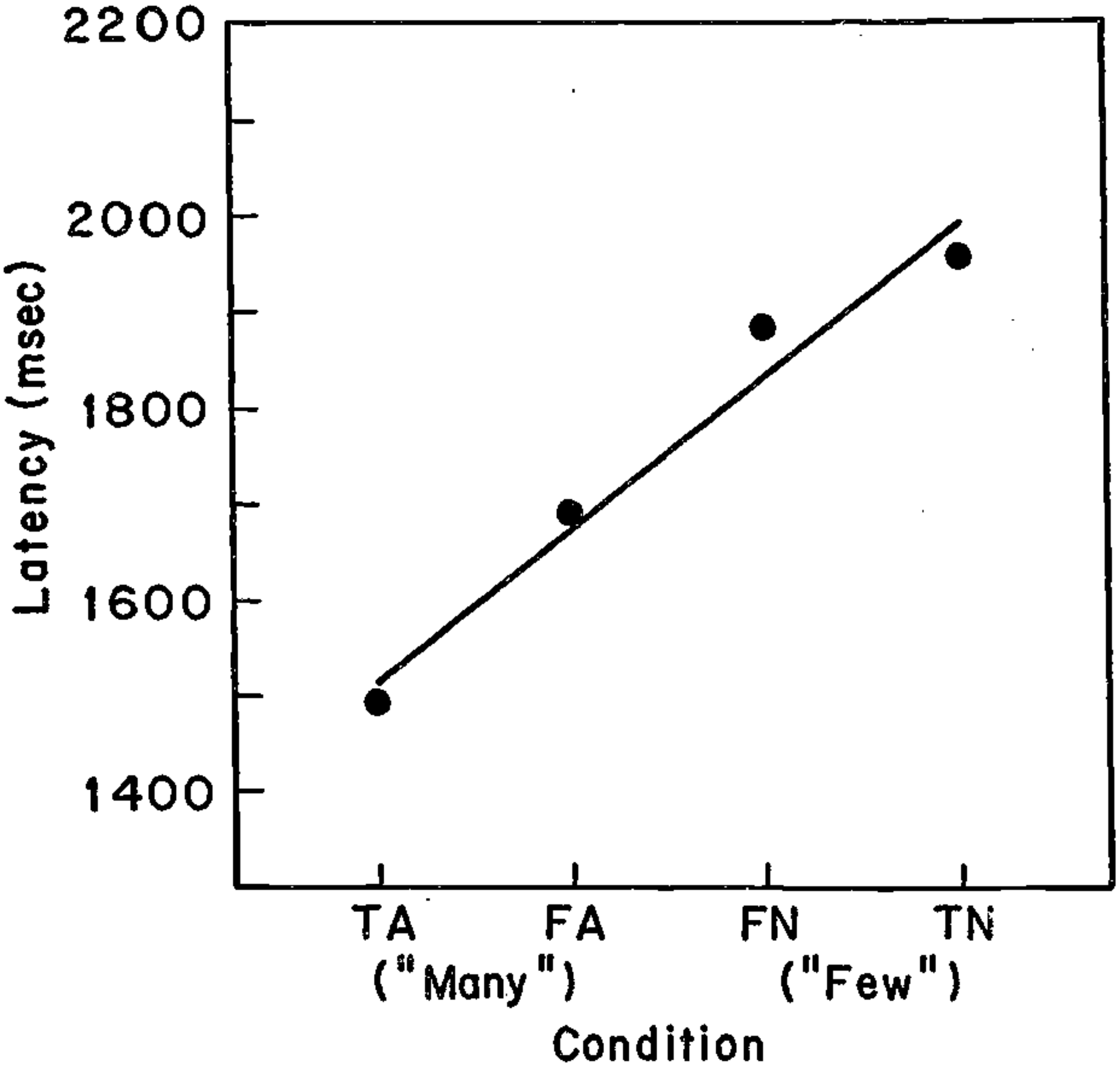


Figure 4. Results from the verification experiment involving implicitly negative quantifiers (data from Carpenter and Just, 1972).

In this experiment, the subject first read the sentence. Then the sentence disappeared and the picture was presented. We simply recorded the locus of the first fixation on the picture using a wide-angle reflection eye camera (Mackworth, 1968). The picture was arranged as in Figure 5. The larger set was always at the bottom; the smaller set was at the top. The subject knew the position of the two sets but didn't know which set would be red and which black. He would have to fixate a subset to determine its color. We hoped that the person would fixate the subset that was in his internal representation of the sentence. If he did, then following a sentence like Few of the dots are red, the person should fixate the larger subset. But following a sentence like A minority of the dots are red, he should look at the smaller subset.

Insert Figure 5 about here

The results, shown in Table 3, show the predicted interaction between quantifiers like few, where subjects tended to look at the large subset, and quantifiers like a minority, where subjects tended to look at the small subset. This interaction was consistent across our 18 subjects. And as expected, subjects looked at the large subset following sentences with quantifiers like many.

Insert Table 3 about here

The importance of this experiment is twofold. First of all, it confirms our hypothesis about the semantic structure of negatives. A sentence like Few of the dots are red is represented as a negation of a proposition about the larger subset. Secondly, the experiment makes an important methodological contribution. It shows that the locus of

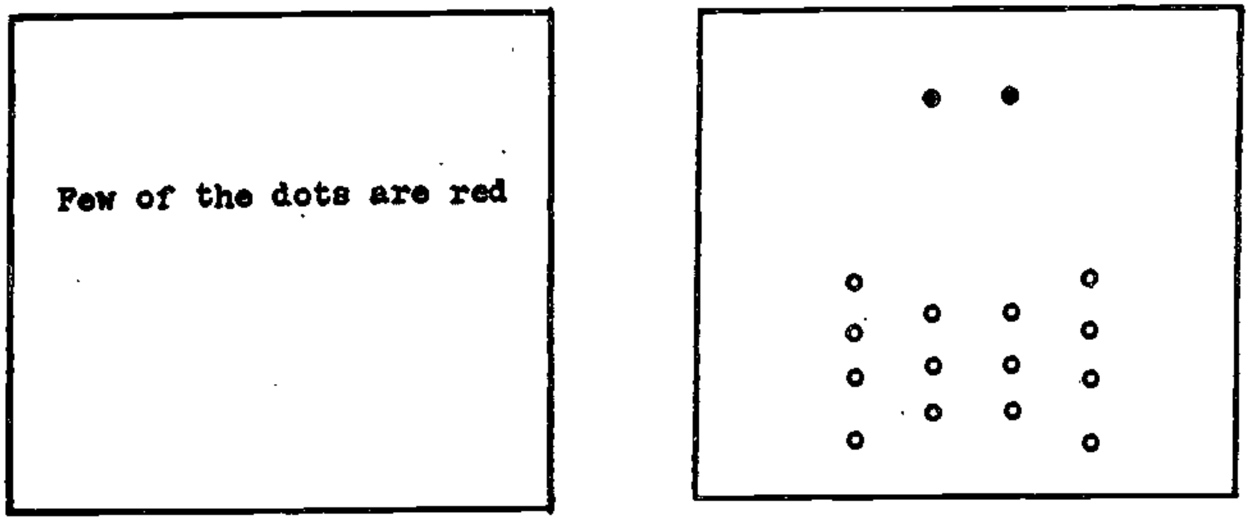


Figure 5. Schematic representation of the relative positions of the sentence and the two subsets of dots in the picture.

TABLE 3

Locus of fixation as a function of sentence type

(Data from Carpenter and Just, 1972)

Example of quantifier (Proposed Representation)	Subset Fixated: Small subset	Subset Fixated: Large subset	Neither	Errors
"A minority" (Aff (Small subset))	43%	23%	25%	9%
"Few" (Neg (Large subset))	26%	36%	30%	8%
"Many" (Aff (Large subset))	6%	59%	31%	4%

an eye fixation can be used to investigate how people represent linguistic information. In this case, superficially similar sentences like Few of the dots are red and A minority of the dots are red, resulted in different patterns of eye fixations. And in fact, the eye fixations reflected the hypothesized internal representations.

In a second experiment, we examined whether or not the duration of eye fixations reflect the mental operations that underlie comprehension. To record the duration of various fixations, we had subjects verify phrases like East or Isn't East which referred to location of a plus, as shown in Table 4. The plus could be in one of four locations. The locations without the plus were filled by asterisks. For example, if the plus were to the West of the sentence, there would be asterisks in the North, South and East locations. The subject fixated a point in the center of the screen and pressed a "ready" button to initiate the onset of the display. Then he was timed and his eye fixations were recorded while he read the sentence and responded.[2] The procedure assured that he initially fixated the sentence. After that, he was free to scan anywhere on the display.

Insert Table 4 about here

We can ask some simple questions about performance in this task. First of all, will the total latencies resemble those for previous experiments? As shown in Figure 6, the total latency is beautifully linear; a straight line accounts for 99.9% of the variance. So this experiment provides an independent confirmation of the processing model.

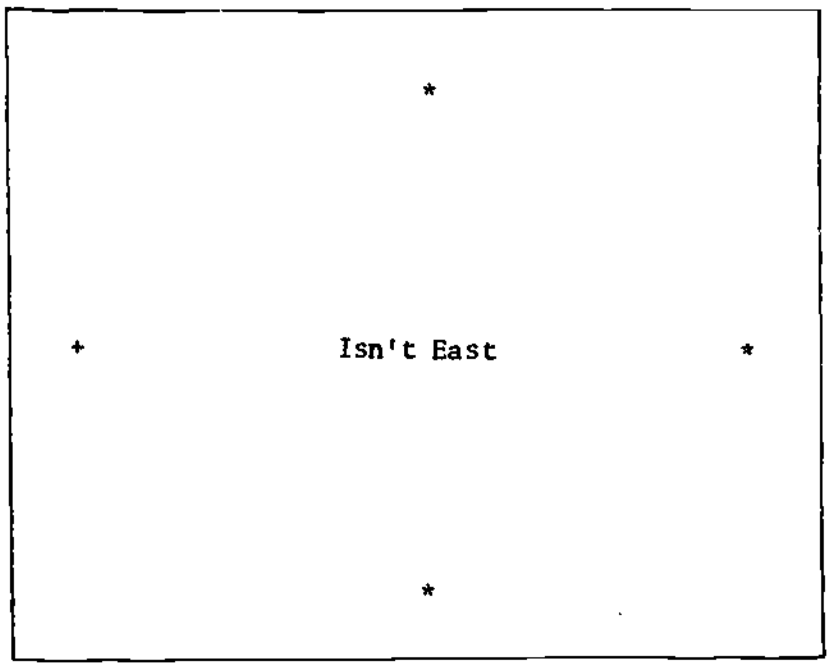
Insert Figure 6 about here

The second question is whether the durations of eye fixations

[2] We thank Chuck Faddis for designing the instrumentation.

TABLE 4

Schematic drawing of a typical stimulus display



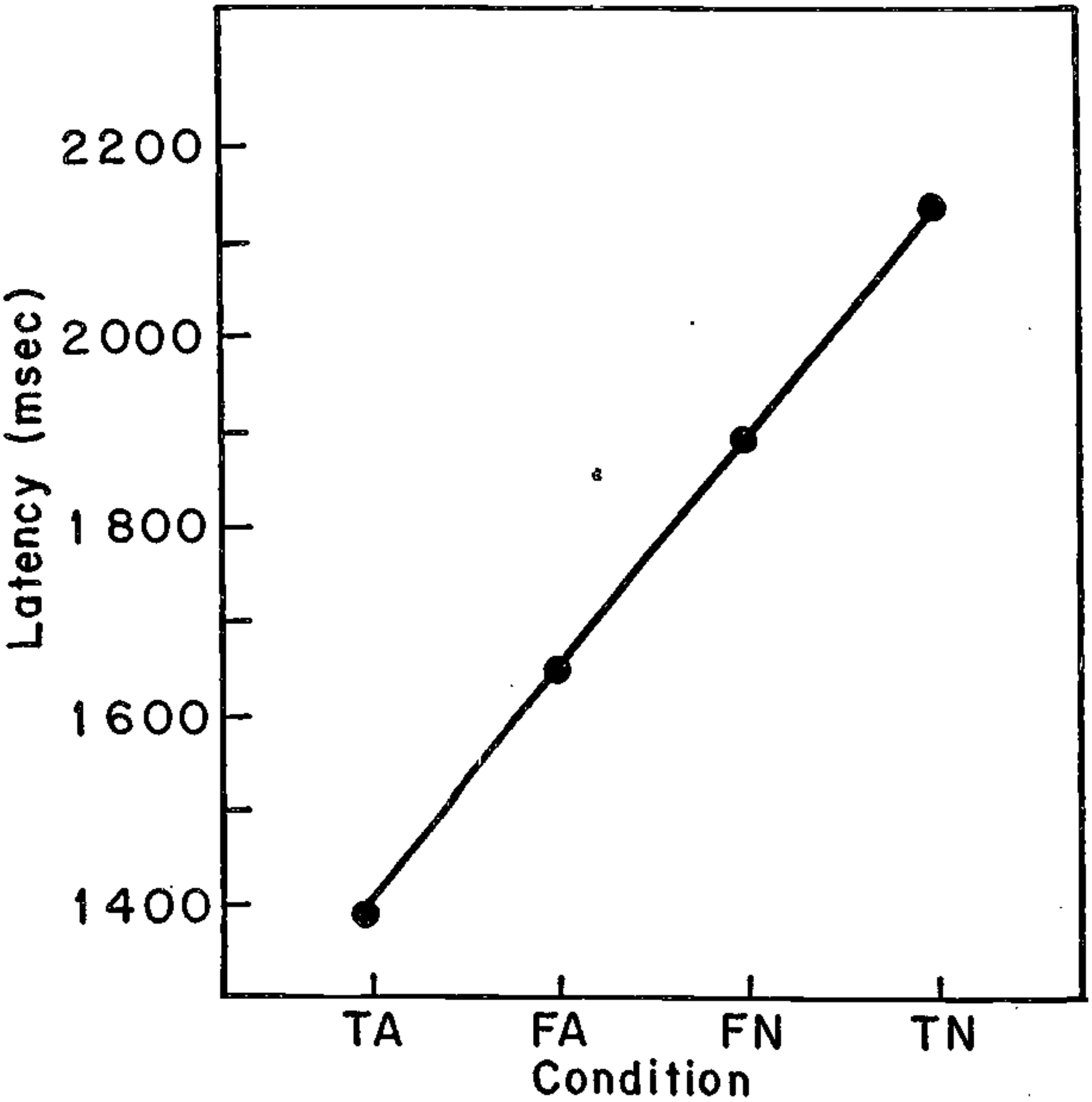


Figure 6. Total latency in the verification experiment.

reflect the mental operations we have proposed in the model of verification--operations such as comparing predicates, comparing polarity markers, and doing extra comparisons after encountering a mismatch between the sentence and picture representations. To answer this question, we computed the average duration that a particular part of the display was fixated in a trial. (For purposes of scoring, the screen was divided into a three by three matrix. All fixations within one of the nine squares were considered equivalent.) In this way, we broke down the total latency into four components. The first component is the duration of the initial fixation on the sentence. This was also the first fixation in a trial. The second component measured the duration of any subsequent fixations on the sentence if there were intervening fixations on other locations. The third component measured how long a person fixated the location mentioned in the sentence. For example, if the sentence said Isn't East, this component measured how long the East square in the display was fixated. Finally, the fourth component measured the time spent in any location other than the sentence or the location mentioned in the sentence.

As Figure 7 shows, the amount of time a person fixated these various locations does reflect the proposed underlying operations. The duration of the first component, the initial fixation on the sentence, is influenced by whether or not there is a negation. The duration is significantly longer when the phrase is negative. The duration of subsequent fixations on the sentence is determined by whether or not there is a negative and whether or not there is a mismatch on the predicate. In other words, this duration is proportional to the hypothesized number of comparison operations. The third component, the time spent on the location mentioned in the sentence, is determined by whether the sentence is affirmative or negative. Again, the duration is significantly longer when the sentence is negative. Finally, the duration of the fourth component, fixations on other locations, is determined by whether or not there is a plus in the location mentioned in the sentence. This duration is significantly longer when there is no plus in the location mentioned in the sentence, namely in the false affirmative and true negative conditions. Thus, all four components reflect the very orderly effects of mismatches between corresponding constituents of the sentence and picture representations.

Insert Figure 7 about here

These results demonstrate two very important points. First of all, the total latency fits the model's predictions. Moreover, each of the four component latencies reflect the kinds of processing stages postulated to underlie verification. It still remains to map the details of these results onto the model. However, the durations of the component latencies seem to reflect processes like comparing constituents. Thus, the duration of eye fixations, as well as the locus of fixations, as shown in the previous experiment, can be used to study comprehension.

What is exciting about this eye movement research is that it is predicated on the hypothesis that eye fixations can be an externalization of the immediate processor. Eye fixations can be used to study what is being attended, encoded, and how it is being operated upon in immediate memory. We have shown that in these tasks, both the locus and duration of fixations reflect mental operations like encoding and

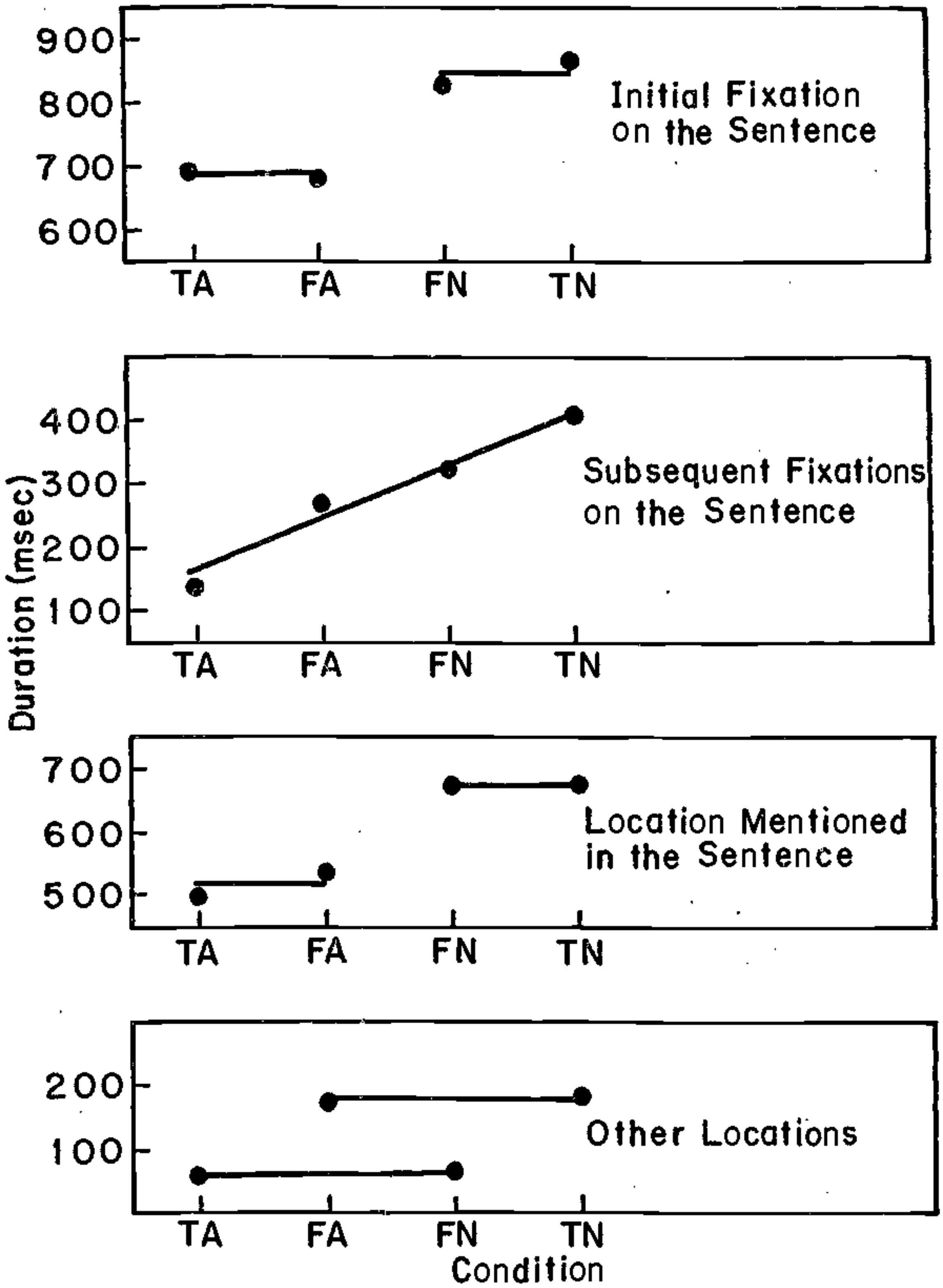


Figure 7. Duration of fixations on various parts of the display.

comparing representations. Thus, this represents a way of studying the extremely rapid mental operations in sentence comprehension.

The mental operations of encoding and comparing representations are not specific to tasks that involve visual scanning. In fact, the processing model presented above can explain sentence verification processes when the task requires that information be retrieved from semantic memory (Cf. Carpenter and Just, 1975; Just, 1974). For example, the model can predict the latencies to verify sentences like Seven isn't an even number or Eight is an odd number, which involve no visual scanning. The model is not concerned with whether the original source of information for a semantic structure is a visual display or previous knowledge of the world. While these will obviously entail somewhat different retrieval and encoding processes, it is the commonalities in processing that are of interest here. The model is concerned primarily with the general processes involved in representing and comparing abstract semantic structures. And the results suggest that this research, including conclusions from the eye fixation experiments, reflect many processes that are common to a variety of comprehension situations. Thus, this eye movement research may provide a way of studying general comprehension processes--not only those that involve visual search.

In summary, there are two main points. The first one is that the locus and duration of eye fixations are very systematically related to the underlying mental operations postulated for sentence verification. The second point is that we know how negatives are represented. A negative is represented as an affirmative core plus a negative tag. The difficulty of understanding negatives comes when that tag mismatches some other source of information. Therefore, we now have the methodology and some of the answers. We can use this approach to investigate other interesting constructions, such as quantifiers, and comparatives. We are making real progress in finding out how people represent and process semantic structures.

DR. MONTY: I noticed you completely stayed away from any tendency to speak to the possibilities of subjects translating from words to mental images. Was this deliberate or were you speaking around it?

DR. CARPENTER: Mental images could be a possible format for certain kinds of processing. The difficulty is in understanding how someone would have a mental image that would correspond to a negative. And so that is why it is probably better to think of this task in terms of a comparison of abstract symbols. The other thing is that the abstract symbolic format suits cases where there may be no real images involved, for example when you're retrieving certain kinds of information from long-term memory: <u>Nixon isn't a Democrat, true or false</u>--as fast as you can. I can predict the latency, and I am not sure that you generate images.

That doesn't preclude imaginal formats for other structures like comparatives and there is a current controversy about that.

DR. COOPER: Have you explored the possibility that whether a word like <u>few</u> is interpreted as a negative or a positive might depend upon surrounding verbal information? For example, if you consider the sentence, <u>Although none of the dots in the group were red, few of the dots in group two were red</u>.

DR. CARPENTER: Actually to make that sentence acceptable, you'd say ... a few of the dots in group two were red. And, a few is an affirmative whereas few is a negative. If you test it with the co-occurrence criteria, this distinction is clear. You can say Few of the boys went, and few of the girls went either, but A few of the boys went and a few of the girls went, either isn't acceptable.

DR. COOPER: Isn't it just possible that depending upon the surrounding words of the critical word, few, few might either be interpreted as a negative or as a positive?

DR. CARPENTER: My tendency is to think that there are cases where people convert negatives like few into affirmatives like a few or a minority. Certainly we do that with explicit negatives. So, we might take something like John isn't home and if we know there are only two alternatives we might internally convert it to John must be at school. And that conversion process, the conditions under which people do it, how long it takes, and what mental operations are involved in transforming sentences, is an interesting question. Whether context encourages such transformations is an empirical question.

DR. HABER: One of the morals that generally the speakers this morning were making and that an awful lot of data suggested was that at least within the context of the reading ability, you could not predict where the next eye movement was going to occur, and the duration of the movements were relatively independent of virtually anything that was tested or manipulated.

Yet you are presenting data which is showing an incredible effect of the kind of mental operations that are being performed on where and for how long the eye lands. Somehow reading ought to fit within the context of what you are discussing. Where is the contradiction?

DR. KOLERS: I think you misrepresented this morning's data. Buswell's data showed clearly that when a person was stuck on a word he spent a large amount of time on it.

DR. HABER: But he did it by making lots of fixations. You went to some length to suggest that the duration of these fixations was a relatively invariant phenomenon. She is showing that it isn't invariant.

DR. CARPENTER: I want to be clear about one thing and then I will answer your question. These data are the average durations spent at a location during a trial not the average duration of a single fixation.

But more to your point is that the decoding component of reading is kind of a minor component in this task. People know what kind of semantic structures are possible. So what I am really tapping and what I meant to tap are the kinds of operations that occur after initial decoding. I am using these operations to reflect on how people must represent information. But for researchers who are interested in the original parsing process, this kind of approach has something to say about what kind of representation the parsing process must come up with.

You have to have parsing operations that derive the kind of structure that fits in with the results of these tasks. But the representation of that parsing process is in that first box. It is a fascinating question. But, we are mainly tapping another stage of the process: what do you do with information once you have represented it.

References

Carpenter, P. A., & Just, M. A. Semantic control of eye movements during picture scanning in a sentence-picture verification task. Perception and Psychophysics, 1972, 12, 61-64.

Carpenter, P. A., & Just, M. A. Sentence comprehension: A psycholinguistic processing model of verification. Psychological Review, 1975, in press.

Chase, W. G., & Clark, H. H. Mental operations in the comparison of sentences and pictures. In L. Gregg (Ed.), Cognition in Learning and Memory. New York: Wiley, 1972, 205-232.

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

Gough, P. B. Grammatical transformations and speed of understanding. Journal of Verbal Learning and Verbal Behavior, 1965, 5, 107-111.

Gough, P. B. The verification of sentences: The effects of delay of evidence and sentence length. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 492-496.

Just, M. A. Comprehending quantified sentences: The relation between sentence-picture and semantic memory verification. Cognitive Psychology, 1974, 6, 216-236.

Just, M. A., & Carpenter, P. A. Comprehension of negation with quantification. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 244-253.

Just, M. A., & Carpenter, P. A. Verbal comprehension in instructional situations. In D. Klahr (Ed.), Cognition and Instruction. Potomac, Maryland: Lawrence Erlbaum Associates, 1975, in press.

Klima, E. S. Negation in English. In J. A. Fodor & J. J. Katz (Eds.), The Structure of Language. Englewood Cliffs, N. J.: Prentice-Hall, 1964, 246-323.

Mackworth, N. H. The wide-angle reflection eye camera for visual choice and pupil size. Perception and Psychophysics, 1968, 3, 32-34.

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

CHAPTER V

This chapter describes some of the major outgrowths of the project that were not discussed in detail in the original research proposal. The research is all related to the topic of linguistic control of information processing. However, the projects span a much wider range of areas, from sentence comprehension and memory to eye fixations as a research methodology. In this chapter, we will briefly summarize the main results of these projects. Copies of each of the papers are provided in the accompanying appendix.

One major area of research has been the processes in sentence comprehension. Through our research, we have developed a precise model of the processes involved in deciding whether a sentence is true or false of an accompanying picture. This model has been generalized to a number of situations and a number of different kinds of sentences. The detailed results and conclusions are included in a paper that is both theoretical and empirical in nature published in January, 1975, in Psychological Review. The paper, "Sentence Comprehension: A psycholinguistic processing model of verification" presents the state of the art in theories of sentence verification and offers a touchstone for future research in the area. It decomposes the processing of a sentence into a number of basic skills, associating particular mental operations with particular stages of processing and measuring the duration of these various stages and operations. A number of converging methodologies, such as measuring reaction times and eye fixations, were used to develop this model.

This work was extended in a number of different directions, one of which was to examine the processing of similar sentences in languages other than English. We examined the verification of sentences in one language that is similar in structure to English (Norwegian) and one that is different (Chinese). In both cases the processing followed the same model we had proposed for the English sentences. This research is described in the paper entitled "Comparative studies of comprehension: An investigation of Chinese, Norwegian and English" which appeared in Memory and Cognition in September, 1975.

Another extension of the sentence verification work demonstrates how the processes used in comprehending a sentence are an important part of how a sentence is recalled. Studies show that subjects use different strategies to deal with different kinds of sentences when they are determining whether they are true or false of the world. This study shows that how a sentence is recalled is determined by the strategy that was used to comprehend the sentence. In particular, subjects process two different kinds of negative sentences in our experiments. One of these sentences they converted to an equivalent affirmative form. For example, if we had given them the sentence It's true that a fire isn't cold, they mentally converted this into It's true that a fire is hot. Some twenty minutes later we tested their incidental memory for this material. Sentences that were converted in comprehension tended to be recalled in a converted form. With other kinds of negative sentences like It isn't true that a fire is cold they didn't convert these into affirmative form during comprehension nor during recall. So the strategy chosen at the time of comprehension determined the representation that was stored in long-term memory and therefore determined the nature of the recall some twenty minutes later. This research is described in a manuscript entitled "The relation between comprehending and remembering some complex sentences;" this manuscript is in press in Memory and Cognition.

In a study that looked at a slightly different aspect of comprehension, we examined how spatial information is stored in long-term memory and compared this to how we retrieve information from pictures that are immediately available. Subjects were asked to either memorize a display of letters arranged in a particular spatial configuration. Then, they were asked to verify sentences as true or false of the picture or of their image. Results showed that while all parts of the picture were equally accessible not all parts of the mental representation were accessible. The mental representation had been stored in a serial fashion such that the information at the beginning of the list was more readily accessible than the information at the end of the list. The search through the long term memory representation of the picture was apparently serial. While mental images may seem introspectively and phenomenologically like real pictures, in fact we can't scan them the way we can scan real pictures. In a picture, we can access some information on the left side as quickly as on the right side. But in an image, the access time is a function of the way it is initially encoded. Generally pictures are encoded from top to bottom so that the information about memorized picture is remembered from top to bottom and recalled from top to bottom and the information is more readily accessible if it were at the top than if it were at the bottom. This research is summarized in the manuscript entitled "The semantics of locative information in pictures and mental images," which is about to appear in the British Journal of Psychology.

Another area of research has focused on the use of eye fixations to study cognitive processes. Chapter IV presents some of our work on eye fixations as a method for studying language comprehension. This line of research is expanded to other domains in a paper entitled "Eye fixations and cognitive processes" which is currently under editorial review. This paper proposes a theoretical basis for the use of eye fixations in research on cognitive processes. The validity and utility of eye fixations is demonstrated in a detailed analysis of eye fixations in three cognitive tasks. In one task, the subject is required to determine whether two pictures are different perspectives of the same object or pictures of two different objects. It has been shown that subjects may mentally rotate the objects in order to determine whether they are the same. The current research shows that there is a very systematic pattern of eye fixations that can be used to track the sequence and duration of mental processes underlying this mental rotation. A second task examines sentence comprehension under conditions in which the subject is forced to first process the sentence and then look at a picture for confirming or disconfirming evidence. In a third task the subject is presented two sets of dots and required to judge which is larger in number. Again, in both of these tasks, the locus and duration of the eye fixations are very closely related to the proposed mental processes. The analysis suggests that there is a very intimate connection between what we look at and what we are thinking about. Thus, eye fixations may provide a key to mental processes that have previously been much less accessible to empirical investigation.

Another area of research has focused on the use of eye fixations to study cognitive processes. Chapter IV presents some of our work on eye fixations as a method for studying language comprehension. This line of research is expanded to other domains in a paper entitled "Eye fixations and cognitive processes" which is currently under editorial review. This paper proposes a theoretical basis for the use of eye fixations in research on cognitive processes. The validity and utility of eye fixations is demonstrated in a detailed analysis of eye fixations in three cognitive tasks. In one task, the subject is required to determine whether two pictures are different perspectives of the same object or pictures of two different objects. It has been shown that subjects may mentally rotate the objects in order to determine whether they are the same. The current research shows that there is a very systematic pattern of eye fixations that can be used to track the sequence and duration of mental processes underlying this mental rotation. A second task examines sentence comprehension under conditions in which the subject is forced to first process the sentence and then look at a picture for confirming or disconfirming evidence. In a third task the subject is presented two sets of dots and required to judge which is larger in number. Again, in both of these tasks, the locus and duration of the eye fixations are very closely related to the proposed mental processes. The analysis suggests that there is a very intimate connection between what we look at and what we are thinking about. Thus, eye fixations may provide a key to mental processes that have previously been much less accessible to empirical investigation.