DOCUMENT RESUME

ED 145 400 | CS 003 741

AUTHOR	Perfetti, Charles A.; Lesgold, Alan M.
TITLE	Discourse Comprehension and Sources of Individual Differences.
INSTITUTION	Pittsburgh Univ., Pa. Learning Research and Development Center.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
REPORT NO	LRDC-1977/1
PUB DATE	77
NOTE	65p.
EDRS PRICE	MF-$0.83 HC-$3.50 Plus Postage.
DESCRIPTORS	Decoding (Reading); Discourse Analysis; Elementary Secondary Education; *Individual Differences; *Literature Reviews; *Reading Comprehension; *Reading Processes; *Reading Research; Reading Skills; Sentences

ABSTRACT

This paper discusses discourse comprehension with respect to individual differences. First, some general principles of discourse structure and the processing of discourse are presented. These principles emphasize the role of sentence and thematic structure. Second, possible sources of individual differences in discourse processing are discussed. Third, research that compares various specific skills in people of differing comprehension abilities is reported. Finally, the authors propose that verbal processes involved in the short-term encoding of language information and in retrieval and use of word names and meanings are a greater source of comprehension skill differences than are strategies related to discourse structure. (Author)

DISCOURSE COMPREHENSION AND SOURCES OF INDIVIDUAL DIFFERENCES

Charles A. Perfetti and Alan M. Lesgold

Learning Research and Development Center

University of Pittsburgh

To appear in M. Just and P. Carpenter (Eds.), Cognitive Processes in Comprehension. Hillsdale, N. J.: Lawrence Erlbaum Associates, in press.

The research reported herein was supported by the Learning Research and Development Center, supported in part by funds from the National Institute of Education (NIE), United States Department of Health, Education, and Welfare. The opinions expressed do not necessarily reflect the position or policy of NIE, and no official endorsement should be inferred. The authors gratefully acknowledge the contribution to this paper of Laura Bell, Mary Curtis, Elyse Finger, Mary Gallagher, Susan Goldman, Thomas Hogaboam, Steven Roth, Patricia Schuetz, Robert Straub, and Linda Swanson. The authors also appreciate discussion they have had with James Voss on some of the topics of this paper.

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DISCOURSE COMPREHENSION AND SOURCES OF INDIVIDUAL DIFFERENCES

Charles A. Perfetti and Alan M. Lesgold

Learning Research and Development Center
University of Pittsburgh

In this paper, we will discuss certain aspects of discourse comprehension with reference to individual differences. The first section briefly describes some general principles of discourse structure and processing, relying in large part on emerging views in cognitive psychology. These principles emphasize particularly the role of sentence and thematic structure in discourse comprehension. In the second section, we discuss possible sources of individual differences in discourse processes. Next, we report some contrastive research on comprehension skill that may serve to constrain theories of individual differences in comprehension. Finally, we propose that certain verbal processes involved in the short-term encoding of linguistic information and in the retrieval and use of word names and meanings may be a greater source of individual differences than structure-related strategies. Throughout the discussion, we assume that comprehension by listening and comprehension by reading are very similar at some sufficiently deep level of analysis, and we will be referring to their common components more than their distinctive ones.

Discourse Structure and Processing Principles

Certain features of discourse structure and related effects of discourse processing characterize most situations of discourse comprehension. We will discuss these features here and la r suggest how they might play a role in individual differences in comprehension. A basic principle is that a sentence within a discourse has two levels of structure. It is organized at the sentence structure level (S) and the thematic level (T). In S-organization, sentences are basic structural units and propositions are basic information units. S-organization is described by rules of syntax that are not discourse-sensitive. However, T-organization is discourse-sensitive and affects S-organization according to certain essentially psychological principles.

Consider the following discourse segment as an illustration of some principles of thematic organization. The segment begins with the 18th line of an excerpt from a historical newspaper account (with names changed to protect the innocent).

18. At one point, the indictment charged, Smith got hold of,
19. and suppressed, a written threat by Jones to disclose the secret
20. cash contribution unless the SEC dropped all proceedings
21. against him.
22. The indictment was announced here as Smith was entering
23. the new Senate office building in Washington, where
24. investigators were waiting to question him about. . . .

This newspaper excerpt demonstrates three principles of T-organization that have some implications for discourse processing and hence for our consideration of individual differences.

1. Proposition elements are thematic to varying extents. One index of an element's thematic value (or thematization) is the number of propositions it has participated in. For example, line 22 contains a proposition with a highly thematized element, the indictment, which has been a part of many previous propositions in which it would have been linked with a number of different predications. By contrast, line 23 contains a proposition lower in thematic elements, viz., that there is a new Senate office building in Washington. There had been few prior

propositions involving its noun referents. Thus, line 22 begins with a highly thematized noun and line 23 does not.

2. Propositions reflect an information structure based on given-new distinctions. The principle is that any sentence contains at least one element of given information and one element of new information. The given-new principle is from Halliday (1967, 1970) and has been discussed by Haviland and Clark (1974) with reference to sentence comprehension. For example, lines 22 and 23 contain some given information, the indictment and Smith, and some new information concerning when the indictment was announced.

3. The psychological salience of different discourse elements can be controlled by the speaker (or writer). Those elements of a discourse that are psychologically salient (available in consciousness) and linguistically unstressed are called foregrounded (Chafe, 1972). Foregrounding thus allows the speaker or writer to control the staging of discourse events. With reference to the newspaper passage, line 24 begins with a nonforegrounded subject noun, investigators, but later includes the foregrounded referent, Smith (him). A continuation of this passage, for example, would be more likely to refer to the investigators or Smith, now both foregrounded, than to the written threat (line 19), now backgrounded.

The S-organization and T-organization are interactive. One level (S) organizes elements of a sentence into appropriate sentence constituents. The other level (T) interrelates propositions contained within and between sentences. These two levels of organization cannot function independently in well-formed discourse, so there is an effect of level T on level S (as well as vice-versa). This effect is achieved through certain linguistic ordering devices and results in the principle that the surface structure of sentences reflects discourse organization principles. Thus, the criteria for well-formed discourses will be based on certain rules interrelating the two levels of discourse organization.

Two experimental examples illustrate how T-organization can influence S-organization. The first is from Perfetti and Goldman (1975), who found that the effectiveness of a noun prompt for sentence recall (S-level) is influenced by whether the noun referent had been thematized by the previous discourse (T-level). Thus, in the Admiral captured the bandit, the relative effectiveness of admiral or bandit to cue recall of the sentence is affected by which noun had participated implicitly in more propositions in the previous discourse. In addition to this T-level effect, the prompt effectiveness of the semantic recipient (bandit in our example) is increased by topicalization (i. e., being placed first in the sentence); hence, it is an S-variable. For a semantic agent (S-variable), only thematization makes a difference. Thus, at the propositional level, S-organization and T-organization are interrelated.

At the surface structure level, their relationship is demonstrated by a second study in which subjects indicated their preferences for sentence forms to conclude a passage (Perfetti & Goldman, 1975). Here, a distinct effect of thematization on topicalization was found, even when neither noun was new information, subjects preferred to begin a sentence with a noun that had been thematized by the discourse.

A second example of this kind of levels interaction in discourse demonstrates an effect of foregrounding on comprehension time. Subjects read brief texts in which the foregrounding of key information was varied (Lesgold, Curtis, & Roth, Note 1). In one condition, Sentence 1 was preceded by several sentences about a camping trip and drive to the forest. It was followed by Sentence 2.

(1) A thick cloud of smoke hung over the forest.

(2) The forest was on fire.

In other conditions, sentences on other discourse topics intervened between (1) and (2), thus momentarily "backgrounding" the information in (1). The measure was time to read and understand Sentence 2. This time was significantly shorter when Sentence 2 immediately followed Sentence 1 than when other sentences intervened. As Table 1 shows, reading time was not affected by how many sentences intervened. Even one unrelated sentence led to longer comprehension times for the key sentence. These examples illustrate that properties of discourse affect processing of sentences in terms of sentence recall, choice of sentence topic, and time to comprehend a sentence.

Table 1

Lesgold and Curtis Foregrounding Study

Condition	Mean Reading Time (sec.)
Foregrounding	
No intervening sentences	2.75
2 more, related	2.99
4 more, related	2.96
Backgrounding	
2 more, unrelated	3.26
4 more, unrelated	3.36
4 more, unrelated, 2 topics	3.39

A schematic diagram of these relationships between theme and foregrounding is given in Figure 1. This scheme is intended to show that global structures have a cumulative effect on comprehension of any particular sentence. In the diagram, each letter refers to a given referent or class of referents. The various subscripted letters refer to specific propositions, so that β_3 and β_5, for example, refer to two different propositions referencing β. The α propositions are those that establish the discourse setting. Thus, they influence which interpretations of subsequent sentences are plausible. At any point in the sequential presentation of a discourse, those referents which are referenced in many propositions are thematized. In the diagram, β is more likely to be thematized than γ, since it is more referenced. In addition, recency of mention and linguistic structure will cause some referents and/or propositions to be foregrounded. Finally, theme and foreground influence comprehension of the next sentence.

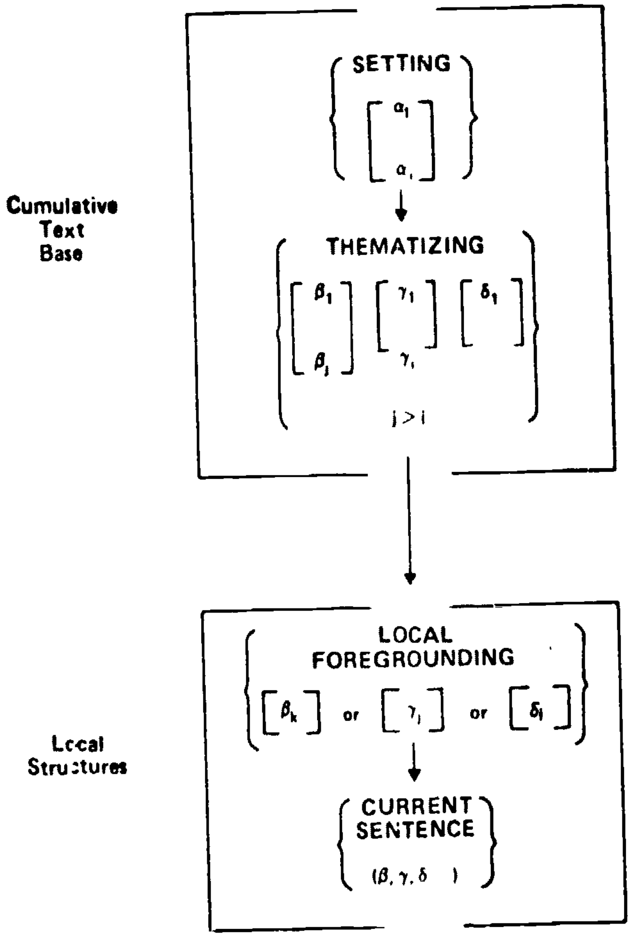

Figure 1. Schematic representation of some discourse organizing principles that affect processing of a given sentence within the discourse

These discourse processes can be placed into a broader frame by considering an overview of the processes during discourse comprehension. Although this problem has not had the kind of formalization seen in text representation (Frederiksen, 1975b; Kintsch, 1974), the following general picture seems accurate, if not very particular. Within a few seconds of hearing (or reading) a given discourse segment, short-term memory (STM) contains features of meaning, syntax, and sound, including phoneme content and also strictly acoustic information, such as the vocal quality of speech. Some of this information is rapidly lost because the various information-processing structures compete for a limited-capacity working memory. The primary work of comprehension is the construction of meanings and hence some semantic representation is the normal outcome of this brief period, although the kind of information that is retained is a function of the specific goals of the comprehension situation.

Questions concerning the short-term semantic analysis of sentences center around the structural units of analysis and the segmentation process that specifies the units. Thus, it is here that structure and process begin to be interrelated. One general possibility is that sentences are recoded from phonetic strings into semantic strings with clause structure determining perceptual units. A well-known illustration of this general assumption is the "click" experiments of Bever and others (summarized in Fodor, Garrett, & Bever, 1974). One difficulty with this processing assumption is that the claim that clause boundaries delimit "perceptual units" is open to the misunderstanding that words are not analyzed ("perceived") until the clause has been "perceived." It is perhaps more appropriate to speak of the clause as a unit of meaning analysis. Word strings, partly analyzed for meaning, may be held in short-term memory until the end of the clause signals semantic synthesis or further analysis and the loss of nonessential information. Here, "nonessential" must be understood as "not undergoing further processing." This is usually, but not necessarily, nonsemantic information.

While phonetic features of spoken language are very salient in short-term memory, semantic information is also clearly available.

The role of clause and sentence boundaries is demonstrated more clearly in the experiments of Jarvella (1971), who found that verbatim recall is at a high level for words in a just-heard clause but much lower for words from the previous sentence. Memory loss for actual words appears to be not a word-by-word affair but more a clause-by-clause affair. Recall of the seventh word back from an interruption is as good as the fourth word when both are from the most recent clause. Otherwise, the fourth word back is better recalled than the seventh word. The interpretation is that the end of a clause signals the occasion for completing the semantic analysis of that clause to allow for the next segment of discourse to take its turn in a capacity-limited memory system.

Thus, sentence constituents are encodable units and sentence boundaries may help regulate the encoding and analysis schedule of working memory. We assume that linguistic structures of the type we have called S-organization serve the function of information processing by providing maximum utilization of limited capacities.

In addition, we assume that T-organization affects processing and suggest that those effects are adaptive to constraints of limited capacity. Consider the principles of T-organization discussed above. One was that elements in a proposition vary in their degree of thematization. This variation may allow more rapid access to the conceptual structure named by a thematized element and facilitate the connection of new predication to this structure. If constituents of a sentence were not differentially thematic, access to the appropriate information structure would be more difficult.

A structure-process relation can also be seen in the second principle, that of the given-new distinction. If at least one part of the sentence is either given earlier in the discourse or is in the presumed shared context of the speaker and hearer, then the work of comprehension is made easier. In general, previously given information should arouse little processing effort. Effective use of limited capacity thus implies deeper processing for new information, scanty processing for given information.

From the processing point of view, the exact source of the given information may not be important. The writer (speaker) may mention a "new" concept in a definite structure that assumes the reader either has the concept in memory or can easily construct it on the spot from old concepts.[1] For example, line 22 begins with information, the indictment, which is discourse-given. In contrast, line 23 contains the new Senate office building in Washington which is memory-given rather than discourse-given.

Structure-process relation in the case of foregrounding was illustrated by the Lesgold et al. (Note 1) data reported in Table 1 and described above. Foregrounding leads to expectations about the topic of the next sentence and also about the nature of the new information it may convey. When these expectations are satisfied, processing is fast. However, when they are not satisfied, there is an extra cost in switching from the foreground-generated pattern of expectations to a new one (cf. Haviland & Clark, 1974).

Thus, the discourse structure concepts of the sort we have been describing are closely related to processing concepts. A schematic diagram summarizing some of these relationships is presented in

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[1]One of the interesting features of discouse is the ability of a speaker or writer to present new information under the guise of given information. If the reader did not know there was a new Senate office building, he does after reading line 23. Certain forms of one-upsmanship have this property of sneaking in new information as if it were memory-given, as when someone is asked if he can recommend a good mechanic and replies with, "I take my new Mercedes to Oil Can Harry's."

Figure 2. It is assumed in this diagram that short-term memory plays a major role in discourse comprehension. It holds some segmented sentence representations and it contains pointers to previously foregrounded information in long-term memory (LTM) as well as to information needed to modify foregrounding for the next sentence. Effective and rapid processing of discourse information can be facilitated by appropriate use of these pointers as well as by other functional properties of STM. From this analysis of discourse, we can now turn to a discussion of its contribution to individual differences. One issue is whether variations in use of discourse pointers or in other STM characteristics are important sources of individual differences.

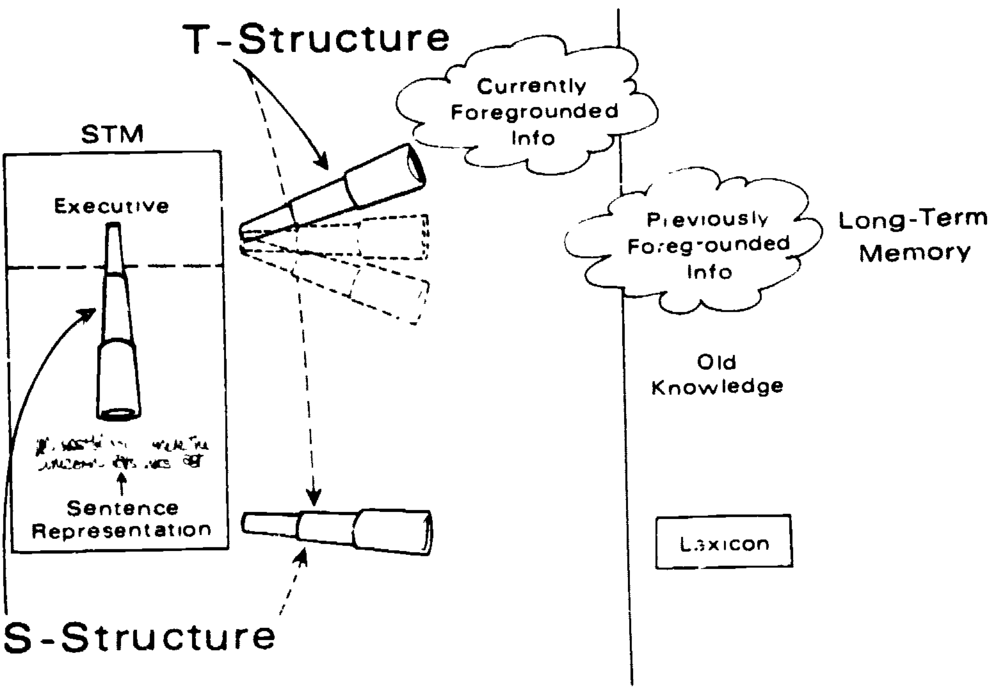

Figure 2 Illustration of possible relationships between concepts of discourse process and discourse structure

Individual Differences in Discourse Comprehension

Within the usual descriptive framework of cognitive processing, there are several possibilities for individual differences in discourse comprehension. Of the many possible sources of individual differences, we will consider only these three: (a) use of discourse structure, (b) STM capacity, and (c) verbal coding speed (see Table 2).

Table 2

Interpretations of Possible Sources of Individual Differences in Discourse Comprehension

I	Use of Discourse Structures	
	A	Macro structures
	B	T-structures
	C	S-structures
II	STM	
	A	STM capacity
	B	STM use
	C	Hysteresis
	D	Specificity/ordering
III	Verbal Coding Speed	
	A	Name coding
	B	Schema retrieval

Use of Discourse Structure

The use of T-structures and S-structures is a possible source of individual differences insofar as individuals are differentially "sensitive" to structural cues to discourse meaning. At the level of S-structure, individuals may differ significantly in their use of clause and sentence boundaries to mark units of processing in working memory.

These boundaries reflect the nature of encoding units and thereby may determine whether the limited capacity is used effectively. To take an extreme case, imagine that a sentence parser somehow identified sentence subjects and used this identification to work on parsed sentences in working memory. Further imagine that it did not complete its parsing until it had (somehow) identified a second subject noun. It would hold the second subject noun while it arranged the material in between the two nouns into a configuration which included the end of the first sentence. Such a system would not be using sentence boundary information to form units in working memory and it would risk overloading and forgetting. By comparison, a parser that (somehow) formed subject-predicate configurations as it identified each predicate would be more effective.

At the level of T-structure, there are other possible sources of individual differences including, at least, use of the given-new distinction and the use of thematic information. Consider the phrase the secret cash contribution in lines 19-20 of the newspaper sample. When the reader encounters this phrase, he is compelled by the definite article the to treat contribution as a previously introduced concept, as some given information. Effective use of this structural information may mean a brief referencing operation on the previously constructed concept. Ineffective use may mean a search and retrieval operation, less brief and more conscious, or even the unnecessary construction of a new concept.

Highly thematized elements should be even more quickly (and automatically) referenced when they are encountered. In fact, there is some evidence consistent with this view from Kintsch, Kozminsky, Streby, McKoon, and Keenan (1975), who found that reading times and recall of brief passages were a function of the number of different arguments (nouns) in the passage. For two passages equal in length and number of propositions, the one with fewer different arguments was read faster and recalled better. Concepts previously encoded presumably require less referencing work than initially introduced concepts.[2]

Thus, individual differences in the use of discourse structure can mean that people differ in their sensitivity to information structure, to thematization, and to clause structure. It may be that the use of T-organization is the hallmark of the skilled comprehender and a source of difficulty for the less skilled comprehender.

A problem that arises in such a view is whether any putative source of individual differences is one of basic processes or of higher-level processing strategies. As a practical matter, the distinction between process and strategy becomes very difficult in discourse comprehension. We suggest defining "strategy" as the knowledge that a procedure or set of procedures apply to a particular problem class. It has the important property that the user of a strategy can identify its main features and can substitute a different strategy when taught it. We prefer to use the term "procedure" to refer to a processing component that executes automatically. It may be "called" by a strategy or triggered by properties of the input data. Thus, we have strategies for winning at checkers (or its more respectable cousin, chess), for mowing the lawn, or for looking for a reference in a text. However, we think that in comprehending language, meanings are often acquired through a set of procedures that are closely tied to the structure and content of the linguistic data. One of our suggestions, then, is that individual differences in discourse comprehension are more likely to be procedural than strategic.

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[2] In addition to possible individual differences in the use of these discourse organizing principles, we would point out that the macro-level of discourse structure is also a potential source of individual differences, (Kintsch, this volume). We have nothing to say about such differences, but we expect that individuals may be found to differ mainly in the availability of a particular higher-order structure in a particular message context rather than in the ability to use higher-order structures.

STM

A second possible source of individual differences has to do with short-term memory (STM), including STM capacity. While there may be limitations in the duration or signal-to-noise ratio of sensory stores which would have implications for reading and listening, the major bottleneck in comprehension may be a limited capacity short-term memory. By assumption, STM size is a fixed source of individual differences in the sense that height and mean diameters of neural axons are sources of individual differences with biological bases. Effects of impoverished STM size in this sense can be seen in mental retardation. On the other hand, except for presumptive cases such as those of severely impaired intellectual functioning, STM size may not be the most interesting source of individual differences. For one thing, it may be a causal factor of relatively low variability for the normal range of individual differences observed. Second, STM size does not show a large developmental increase. Chi (1976) has argued that STM capacity does not increase between five years and adulthood. As a general principle, we suggest that those aspects of cognitive processing which are significant sources of individual differences are those that show significant ontogenic development. If STM size does not develop with age, it is not likely to be a major factor within the normal range of individual differences.

Equally important is the distinction between the size of STM and its functional capacity. By functional capacity, we mean the use of STM in verbally encoding material during a discourse task. It is possible that some of the observed memory performance differences are due to procedures for making use of STM capacity rather than to inherent size differences per se (cf. Case, 1974; Chi, 1976: Huttenlocher & Burke, 1976). We will return later to alternative ways of interpreting STM differences.

Speed of Verbal Coding

The third source of individual differences in discourse processing is speed of verbal coding. Hunt (1976; Hunt, Frost, & Lunneborg, 1973) has demonstrated that adults classifiable as high verbal and low verbal can be distinguished by performance on certain cognitive tasks that can be interpreted as involving either quality or speed of verbal encoding. In the case of reading, we have argued that speed of verbal coding is a critical distinguishing feature of skilled reading (Perfetti, in press; Perfetti & Lesgold, Note 2). Both rapid phonological coding and rapid semantic coding are more characteristic of skilled readers than less skilled readers.

In the general context of language comprehension, verbal coding differences have two components: the rapid access and retrieval of a word name and the retrieval of its contextually constrained semantic properties. Since STM works primarily with categorized speech sounds, the first is not necessarily a trivial problem. Memory capacity limits require that costs be paid for low quality verbal codings.

Notice that retrieving verbal names and relevant meanings is related to the structure of long-term memory. Semantic memory differences are indeed a major component of comprehension differences. It may not be sufficient to note that two individuals have comparable vocabularies in some static structural sense. They may differ substantially in their effective use of words and word meaning in given discourse contexts. While we know of no direct evidence linking poor comprehension to slow semantic access in discourse, we do have some evidence suggesting that less skilled readers take longer to make simple semantic judgments of words than do skilled readers, even when phonological decoding time is subtracted out (Perfetti, Hogaboam, & Bell, reported in Perfetti & Lesgold, Note 2).

Some Studies of Individual Differences in Comprehension Skill

So far, we have discussed general features of discourse and possible sources of individual differences in discourse processing. We turn now to some empirical work that may partly constrain theories of how skilled comprehenders handle discourse differently from less skilled comprehenders. In these experiments, our attention to individual differences has been in terms of reading achievement scores of children and adults. However, we believe that, granting certain appropriate caveats, we are discussing issues of comprehension and not just reading. We should also note that we are generally reporting data for dichotomously classified individuals. This is a practical matter and we assume that generally we are dealing with continua of processing skills along which individuals can systematically vary. With respect to the possible sources of individual differences outlined above, most of the research we report has something to say about use of discourse structure, capacity and use of STM, and speed of verbal coding. We begin with experiments having to do with S-structure and short-term memory.

Individual Differences in Short-Term Discourse Memory

One means for testing S-structure hypotheses is the probe discourse experiment (Perfetti & Goldman, 1976), similar in purpose to the studies of Jarvella (1971) on discourse memory, and in procedure to the studies of digit memory by Waugh and Norman (1965). In a probe discourse experiment, a subject hears or reads some discourse such as a long story, a brief passage, or a list of sentences. Occasionally and unpredictably, the subject is presented a memory probe, a word that occurred earlier, but recently, in the discourse. The subject's task is to produce the word (the target word) that had followed the probe word in the discourse. In these experiments, two types of variables have usually been manipulated. One is the number of words that have intervened between the target and the probe. The second is the structure of the discourse intervening between the target and the probe.

In the first experiment, a structural variable was whether the target was from the sentence being read (i. e., within a single sentence boundary) or from the prior sentence (i. e., across a sentence boundary). Orthographically, the target word was either three words back or six words from the test point. The questions of interest were whether recall would be greater from within a sentence than across a boundary and whether this boundary effect would hold more for skilled readers than for less skilled. Such an interaction would be support for one version of the hypothesis that S-structure is a source of individual differences.

Passages were read both aloud and silently by third- and fourth-grade subjects. When a subject turned a page, he usually encountered a page continuing the story, but on 18 occasions during a 45-50 page story, he encountered a probe word when he turned a page. The probe and its target had occurred on the previous page. Subjects were told of a comprehension test that followed reading in order to encourage reading for meaning. Subjects within each grade were classified as skilled and less skilled readers according to scores on the Metropolitan Reading Test. However, the two reader groups were closely matched on mean IQ.

The verbatim recall, summarized in Table 3, shows that skilled subjects recalled more targets than less skilled subjects, $F(1,24) = 9.54$, $p < .001$; recall was better in oral reading than silent reading, $F(1,24) = 5.30$, $p < .04$; and targets with three intervening words were recalled better than those with six, $F(1,24) = 5.30$, $p < .04$. However, the difference in the number of intervening words was restricted to cases in which a sentence boundary intervened. When a sentence boundary intervened, there was a large effect of target distance. By contrast, if the target was from the current sentence, it did not matter whether it was three words or six words back.

Table 3

Probe Recall During Reading for High and Low Skill Subjects
(From Perfetti, Bell, & Goldman, Note 3)

	Relation of Probe and Target			
	Within Sentences		Across Sentences	
No. of Intervening Words	3	6	3	6
Oral				
High Skill	.85	.83	85	63
Low Skill	82	79	81	48
Silent				
High Skill	78	.81	.79	.69
Low Skill	.71	67	77	47

Summary

High Skill	76	Oral	74	3 words within	80	6 words within	.78
Low Skill	.67	Silent	70	3 words across	79	6 words across	56

Note. Data are verbatim recall probabilities combined over two age levels. Since summary data are unweighted over three conditions, they are not identical to means computed from cells of table.

An important result is that the sentence boundary effect did not interact with reading skill. In other words, sentence organization of the sort reflected by the sentence boundary effect does not appear to distinguish high from low skill readers in this task. However, there was a tendency, not statistically significant, for less skilled readers to have especially low recall for a six-back, across-boundary target. Also, when the number of intervening words becomes as large as 11, some difference between high and low skill in the boundary effect can be found (Perfetti, Bell, & Goldman, Note 3). Here, low skill readers show low recall both from within the current sentence and from across the sentence boundary. We interpret this as demonstrating some limitations on the sentence boundary effect imposed by rate of verbal coding. Slow decoding contributes to functional memory loss for the beginning of long sentences.

One point to emphasize is that the superiority of skilled subjects is not confined to a verbatim measure. Relaxing the performance criterion to include meaning-preserving paraphrases did not diminish their advantage. The main effect of a relaxed criterion is to eliminate the advantage of oral reading over silent reading. Apparently, oral reading provides an acoustic input of the text which keeps the verbatim form available in auditory short-term memory. In silent reading, verbatim information, but not necessarily meaning, is lost more rapidly.

To summarize the main points so far: For short-term memory during reading, skilled readers remember more from the prior sentence than less skilled readers; within the limits of six intervening content words, readers, whether high or low skill, remember more from within the sentence they are reading than from the previously read sentence.

Although the finding that skilled readers remember more of what they read is not surprising, such a result has important implications. It emphasizes the importance of processes involved in the encoding and immediate organization in memory of words and phrases rather than more global discourse organization and retrieval processes. We would suggest the possibility that observable differences among readers in their ability to recall a passage are largely accounted for by difference during the actual encoding of sentences during passage reading.

Furthermore, there is reason to believe that this general picture holds for listening as well as reading. Data from a study by Perfetti and Goldman (1976) illustrate the evidence for this. This experiment was essentially a listening version of the experiment just described although there were some important differences. One difference was that the number of intervening words before the probe test was much greater, 6-8 for a near probe and 13-15 for a far probe. A second difference was that some test sentences contained two clauses, and whether the order of clauses was subordinate (S) clause followed by main (M) or vice-versa was a variable.

An example of the materials follows:

Type M, S.:	It had been a beautiful day for rowing. Nick began to have trouble, when a thick fog came in from the sea. (Probe)
Type S, M.:	It had been a beautiful day for rowing. When a thick fog came in from the sea, Nick began to have trouble. (Probe)
Type S. M.:	It had been a beautiful day for rowing, when a thick fog came in from the sea. Nick began to have trouble. (Probe)

As in the previously described experiment, subjects were separated by reading achievement tests but were matched on IQ. Subjects were third and fifth graders.

Although this was a listening task, skilled readers were higher in probe memory performance than were less skilled readers, as can be seen in Table 4. Furthermore, group differences are observed for near (about 7 back) and far (about 14 back) probes and for both types of two-clause sentences (M, S and S, M). However, differences are negligible for one-clause sentences (S. M), especially for a near probe.[3]

[3]This negligible difference with about seven intervening words contrasts with the results of the reading probe memory experiment in which there were significant reader differences at six intervening words. This contrast may reflect the difference between reading and listening for less skilled readers. We know that less skilled readers take longer to decode a single printed word compared with skilled readers (Perfetti & Hogaboam, 1975). This decoding factor may cause memory differences between readers to appear with fewer intervening words in reading compared with listening.

Table 4

Probe Memory for Listening Task Probability of Target Recall
(From Perfetti & Goldman, 1976)

Number of Intervening Words	Sentence Type M,S		S,M		S.M	
	7	14	7	14	7	14
3rd Grade						
High Skill	77	63	92	50	85	23
Low Skill	54	44	67	38	83	21
5th Grade						
High Skill	90	71	96	60	98	.29
Low Skill	67	63	88	52	96	17

The significance of this result is that it suggests that the processing demands that accompany clause integration may be an important source of individual differences. For a single-clause sentence, the encoding of a less skilled comprehender is sufficient to permit memory for the beginning of the sentence. But encoding a second clause requires more work and both it and the preceding clause become less available to the less skilled comprehender.

Individual differences with respect to sentence boundaries are not to be found in these data. The effect of a sentence boundary can be seen in the S. M condition, comparing the near condition (within) with the far (across). The near-far difference was greater here than when there was no sentence boundary between a near and far probe. However, the boundary is equally a factor for skilled and less skilled readers. Jarvella (1971) suggested that sentence boundaries serve to signal the end of active storage of words in short-term memory and they appear to do so without respect to any obvious individual differences.

An explanation for discourse memory differences might be sought in terms of memory capacity. Such an argument would be consistent with the notion that data and processes compete for the same limited capacity (Baddeley & Hitch. 1974). We have already argued that there are other interpretations of discourse memory differences, and here we have some data on the same subjects that may support this argument. The subjects in the experiment just described also were presented with lists of digits on audio tape for a probe memory experiment. The probe procedure is that of Waugh and Norman (1965), who used it to estimate primary capacity. It also has the property of being procedurally analogous to the probe discourse task since subjects are required to recall the digit that had followed the probe digit in the string.

The number of digits intervening before the probe test ranged from one to nine. The result was simply that there were no significant differences between reader groups (Perfetti & Goldman, 1976).

What this suggests is that effective STM capacity in processing for discourse is a source of individual differences when STM size per se is not. One possible explanation of the discourse memory effect is that the task requires rapid decoding and encoding of linguistic units. Words and phrases are decoded and must be kept alive in memory to be rearranged and encoded into full sentences or propositions. A rapid shifting of attention among coding operations is a constant demand in discourse processing. Compare this with the case of digits. Here there is one kind of processing, digit names. They belong to a small, well-defined set and the memory demands are, so to speak, one-dimensional. In terms of retaining information in short-term memory, one might think of the difference between Craik and Lockhart's (1972) Type I and Type II rehearsal. Type II is needed in comprehending discourse, but Type I is sufficient for digits.

Our hypothesis is that the memory differences are a question of encoding processes that are typical of language comprehension, although not necessarily unique to it. What goes on in discourse processing is a sort of three-ring circus. Word names are decoded, relevant conceptual information is stored with word names, conceptual information is retrieved as part of word names, and relevant syntactic relations are encoded (not necessarily in a bottom-up direction). That means that at least pairs of word names and their conceptual features are encoded into meaningful configurations. This requires a good deal of precision verbal juggling. There is evidence from Hunt and his colleagues (Hunt et al., 1973) that there are significant individual differences in speed of verbal processing. It is a small step to suppose that verbal processing speed is a particularly significant factor in something as complex as the processing of connected discourse. Our position is that verbal coding speed is a general factor in comprehension, that it applies to both listening and reading, and that it is relatively insensitive to strategy differences.

We have some additional research (Perfetti, Hogaboam, & Harned, Note 4) that supports the conclusion that verbal coding speed rather than use of sentence structure distinguishes the skilled from the less skilled. The task was a phoneme monitoring task where subjects monitored for a /b/ or /d/ in a list of words or in a sentence. In addition, the subjects were required to remember the word lists and to orally reproduce each list after its completion. In the case of sentences, they were required to paraphrase each sentence a few seconds after its completion. The following are examples of the sentences from this task.

(3) The barn (1↓) on the hill looked like a very small house from . . .

(4) The tall thin boy (2↓) from across the street . . .

(5) A friendly old man fed the birds (3↓) every morning at five . . .

(6) The playful little kitten hid the small red bag (4↓) under a chair . . .

The relative position of the target within the sentence and within the word list was varied, as indicated by the numbers in (3)-(6). In the case of sentences, Targets 1 and 2 are from the subject-noun phrase of the sentence and 3 and 4 are from the verb phrase: The phoneme targets were all contained in common one-syllable words--words like boy, bird, desk, and doll. Subjects were IQ matched 10-year-olds, classified as skilled and less skilled in reading comprehension.

As Figure 3 indicates, there were generally shorter detection times for the skilled group compared with the less skilled group.

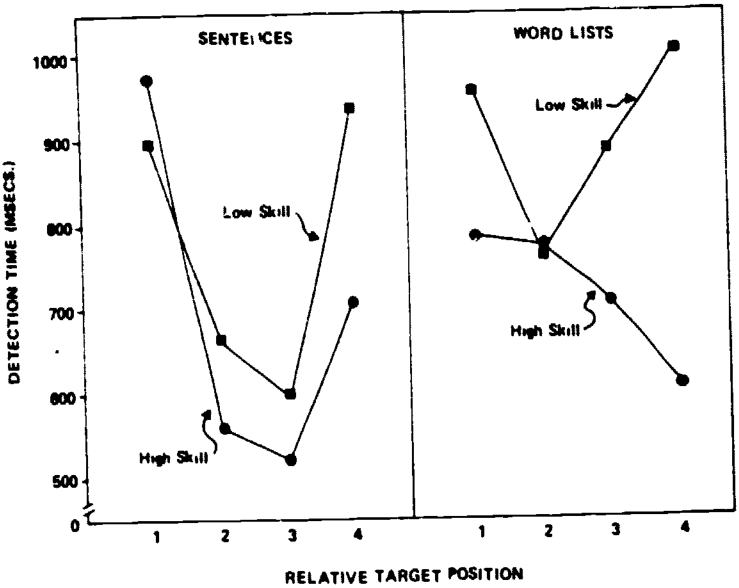

Figure 3 Phoneme detection time as a function of relative position of target word within a sentence and within a word list (Unpublished data of Perfetti, Hogaboam, & Harned, Note 4)

One might suggest that such differences are due to something like spelling ability, which is obviously related to reading ability, and therefore uninteresting. But these were words, and we think that any of our subjects could have quickly told us that bird begins with b. Instead, we take it as an example of differences in rapid access and retrieval of verbal codes, perhaps the word name. It could be the last stage of the process that produced the difference (i.e., deciding that the retrieved word name contained the targe''. Even this, however, is compatible with the hypothesis that verbal processing is the problem since concomitant comprehension demands are sharing the verbal processor.

In support of this explanation, another aspect of the data is significant. Both subject groups were faster on sentences than on word lists, indicating that there was some facilitation due to sentence structure. However, the less skilled subjects were helped at least as much as the skilled subjects. We have no evidence of a strategy difference related to S-organization. The only obvious interaction concerns position--skilled subjects were much faster at the end of a word list. A likely explanation for this is the taxing load placed on low- erbal subjects as they get further into a list that they are trying to learn for later recall. Skilled subjects may be processing more efficiently and therefore not overloading processing capacity. Again, we have no evidence here that supports use of sentence structure as a source of individual differences.

Structures (T-organization) and Strategies

So far, we have shown that an important source of individual differences is short-term memory for discourse and have suggested that speed of verbal processing rather than STM size or S-organization might be involved. We have not found any obvious qualitative differences between skilled and less skilled comprehenders that would shed light on how use of sentence structure is different. However, it is possible that individual differences are a function of the sort of inter-sentence organization we referred to as T-structure.

First, consider whether skilled readers might be better at higher-order semantic organization of a text. To study this question, Berger (1975) examined whether high-skill or low-skill children differ in how they recall a passage or answer literal questions about it. The hypothesis was that only recall would show big differences between high and low skill since recall should be sensitive to overall passage organization. By contrast, a test made up of literal Wh-type questions should show little or no difference since the form of the question provides a direct cue to the required information, thus making overall organization less important for retrieval. However, the prediction was not confirmed: Differences between groups were substantial for both types of test. Moreover, the texts were analyzed for proposition content and there were no differences in the patterns of propositions recalled by the two groups. Although more sensitive organization measures need to be examined (e.g., Frederiksen, 1975b), at least global text organization processes appear not to be an important source of individual differences.

One aspect of the T-structure hypothesis is that individuals vary in their sensitivity to discourse structure. In particular, it is possible that rapid access and re-use of previously encoded concepts is the locus of skill differences in discourse comprehension. If comprehension skill differences are due to this kind of "sensitivity" difference to T-structure, then the memory advantage of high-skill individuals in a probe discourse task might be expected to diminish when discourse is made less thematic. An additional assumption leads to a related hypothesis. If it can be assumed that importance of discourse structure increases as one gets further into a discourse, then it might also be expected that the differences between high and low skill comprehenders will increase with distance into the discourse.

Both of these hypotheses were tested in a probe discourse experiment. Passages were presented to subjects in such a way that each third of the passage provided data on discourse memory that could be compared with memory for other thirds. Secondly, passages were context-scrambled as well as normal. Context scrambling meant that the same 40 or so test sentences were presented on the same page in exactly the same order as in the normal story. The only difference was that the sentences intervening between test sentences were randomly selected from the normal story (i.e., the context was scrambled). There was still another condition in which pairs of sentences were presented without any relationship among pairs. That is, it was a list of paired sentences. If skilled readers take advantage of discourse structure more than less skilled readers, their advantage should be greatest with normal passages and reduced for context-scrambled passages and sentence pairs. Secondly, their memory superiority would increase in successive thirds of the normal passages. Some of the data from this study are shown in Table 5.

Table 5

Probe Recall Data for 4th-Grade Subjects on Context Experiment

	Discourse Type		
Group	Context Normal	Context Scrambled	Sentence Pairs
High Skill	79[a]	67	.73
Low Skill	63	59	55

[a]Target verbatim recall for reading averaged over thirds of the passage Sentence pair data are from listening task

Basically, there is little support for either hypothesis. There was no difference for either group across the three thirds of any of the passages. While skilled readers appeared to be aided slightly more by having a proper passage than were less skilled readers, the difference was not significant. More important, the two groups differed as much on pairs of sentences, a minimal discourse condition, as on proper passages. This last fact supports the interpretation that the individual differences observed in the probe discourse task do not involve T-structure or any more global discourse organization.

However, suppose it is true that skilled and less skilled readers are differentially sensitive to discourse features. For example, the recognition and use of previously accessed concepts may be a major source of individual differences. Perhaps skilled readers are more sensitive to the given-new distinction than less skilled readers; the skilled reader may be better at recognizing and accessing given information.

To determine if both skilled and less skilled readers are sensitive to the given-new distinction, we timed subjects while they read pairs of sentences (Lesgold Curtis, & Gallagher, Note 5). The procedure, adapted from Haviland and Clark (1974), was to present a pair where the second sentence presupposed that some information was previously given. For example, consider the pair:

(7) a. Jane decided not to sit on the grass.
    b. The grass was wet.

The second sentence marks the grass as given information; in fact, the previous sentence specified the existence of some particular grass. Thus, the pair of sentences should be relatively easy to comprehend. By contrast, consider the sentences:

(8) a. Jane likes the smell of freshly cut grass.
    b. The grass was wet.

This pair should be more difficult to comprehend because the information marked as given in the second sentence is not previously specified; the first sentence does not specify the existence of some particular grass. Haviland and Clark (1974) found that the comprehension time for adults was 60 msec faster for the second sentence when it followed "direct antecedents" like (7)a than when it followed "indirect antecedents" like (8)a.

The research question we examined was whether skilled and less skilled readers would show the same sensitivity to this violation of the given information in sentences like (8). We tested 32 fifth graders, half of whom were below grade level on several reading subtests and half of whom were at or above grade level. Both the less skilled readers and skilled readers showed slower reading times for sentences where the information marked as given in the final sentence had not been previously specified by the initial sentence. For the skilled readers, the difference between direct and indirect antecedents was similar to the different Haviland and Clark found with adults (1990 msec vs. 2047 msec). Interestingly, the less skilled readers showed an even larger difference (3436 msec vs. 3674 msec). Thus, both groups of subjects are sensitive to the given-new distinction. While the less skilled readers are slower overall, they are able to recognize and utilize given concepts. Thus, less skilled readers are sensitive to discourse properties such as given-new. This is further support for our view that sensitivity to discourse structures does not differentiate skilled and less skilled readers.

In addition to the textual coherence functions of given information, there is a hypothesis concerning processing demands that follows from the given-new distinction. To the extent that comprehension is a matter of rapid verbal processing in a limited capacity memory system, effects of comprehension demands can be seen on the memory for previously encoded words. In particular, in the probe discourse task previously described, memory for a target word given a probe should be related to whether given or new information intervened between the target and the probe test. The hypothesis is that given information should be less of a processing load than new information. The given information has already been accessed and can therefore be more readily used than the new information. Furthermore, if good readers are more sensitive to this distinction, then given information ought to be less of a processing load for skilled readers than for less skilled readers, relative to new information.

To test these hypotheses, Straub (Note 6) used a probe discourse procedure, varying whether the brief text segment between target and probe was a restatement of previously given information or represented new information in its initial statement. Adults, separated as high and low readers by scores on the Davis Reading Test, and 10-year-old children, separated by a standardized reading achievement test, were subjects. The adults read a story that was displayed three or four lines at a time on a computer terminal with pacing under their control. The children heard the same stories on audio tape so that the effects of information structure would not be dependent on decoding, which is one component of reading that we know to be a problem for many less skilled readers. Results are shown in Table 6.

Table 3

Probe Recall Probability Following Given and New Information Structures (From Straub Note 6)

	Intervening Information		
	Given	New	Difference
College Students			
High	76	42	34
Low	56	30	26
Fourth Grade			
High	64	24	40
Low	24	16	08

A major result of interest is the effect of information structure. Overall, for both adults and 10-year-old children, the probability of target recall was nearly twice as great when the intervening sentence fragment was given as when the intervening sentence fragment was new. For example, adults recalled 66% of targets following given information and 36% following new information. Thus, there is support for the assumption that the probe procedure is sensitive to the amount of comprehension effort. Given information may require less processing capacity to be comprehended since it is likely to be a restatement of something recently comprehended (at least in part). New information, on the other hand, requires more extensive processing and thus may force forgetting of current or previous STM content.

A second result of importance is the skill differences. For adults, high skilled subjects recalled more than less skilled subjects, as one would expect. However, there was no indication of an interaction between skill level and information structure. For the adult readers, skill differences did not appear to be a matter of different abilities to use given information.

For the 10-year-old subjects, a different pattern was observed. Here, there was a significant interaction between reading skill and information structure.[4] The high-skilled children seemed to benefit more from given information than did the less skilled children. One interpretation of the data would be that the less skilled children do not distinguish between given and new information. However, the previous study makes this interpretation somewhat unlikely. Our interpretation is that the difficulty of the task, in which adult-level materials were used, limited the possibility for the given information to show an effect for the less skilled 10-year-olds. Supporting this view is the fact that the level of performance was extremely low for this group.

The research we have discussed here certainly has not examined all the ways in which discourse structures might be sources of individual

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[4]The interaction reported here, and those elsewhere in this chapter, depend on the assumption that proportion of targets recalled in a discourse task reflects an underlying equal interval scale. It is possible that measures of accuracy sometimes fail to meet this assumption. Converging evidence from other tasks or measures is required to increase confidence that observed effects represent processing differences.

differences in comprehension. In fact, it has touched on only some of those discourse structures we included as examples of T-structure. Other research may discover important discourse structure effects at the levels of organization we have been considering. However, our experience so far has led us to expect less from discourse organization at this level than from other more localized components of discourse comprehension.

The Speed-Completeness Tradeoff

Some of the experiments presented above examined individual differences in processing time for some of the component processes of comprehension. However, it is also possible to examine the adequacy of comprehension achieved within a fixed study period. If the less skilled comprehender is slower in the basic process components of comprehension and if his running memory for working is less, then he should show a strong speed-completeness tradeoff, having a lower level of comprehension whenever time is limited. We turn now to three experiments by Lesgold, Curtis, and Roth (Note 1) which used a single set of discourse materials and varied the processing and speed demands on the comprehender.

In each study, participants either read or heard four unrelated paragraphs and then were prompted for written paraphrase recall of each of the paragraphs in turn (after having studied all four). The paragraphs had a common macrostructure but shared no semantic relationships. Each consisted of one topic sentence which introduced four members of a category followed by four sentences about each of the four different category members. In one passage, four First Ladies were discussed. In another, four wild fruits were described and their uses were specified. A third described the roles of four animals in an animal mythology, and the remaining passage told about a woman considering the merits of four different fictional cities to which she could move.

There were two forms of each passage, differing in the ordering of sentences. Both passage types started with the topic sentence. In the normal passages, all four sentences about a particular category member occurred in sequence; in the scrambled passages, the order of sentences was random. As can be seen from Table 7, both forms looked like acceptable prose; the scrambled passages looked more like comparisons of the category members while the normal passages looked more like item-by-item descriptions of each category member in turn.

The subjects for all three experiments were adults from introductory psychology classes. They were pretested with the Davis Reading Test (in modified form, viz., half the usual time to answer only the first half of the test questions, for the second and third experiments). For each experiment, the sample was split at the Davis median. As in the Hunt (Hunt et al., 1973) and Straub (Note 6) studies described previously, we really compared excellence to adequacy in these studies since we estimate that the average reader in the low group was close to the 50th percentile for college freshmen.

The three studies differed in how the passages were processed, listening vs. reading, and in the rate of discourse processing that the task conditions induced. The first experiment was an auditory presentation of the passages at normal speech rate. In Experiment 2, one sentence at a time was displayed on a computer terminal screen and the subject was told to take as long as he wishes to study and understand each sentence, pressing the space bar when he wanted to see the next. In Experiment 3, the subject received the whole passage at once on a piece of paper, and read through it once at his own speed. In all three experiments, recall protocols were scored for the number of passage propositions they contained. The data for all three experiments are summarized in Table 8.

Table 7

Sample of Passage Variations in Prose Comprehension Studies

<u>Normal Version</u>

Each of the first ladies made a special imprint upon the White House. Eleanor Roosevelt's life was filled with visitors from early morning until late at night. Mrs. Roosevelt believed in physical exercise, and encouraged her staff to do calisthenics At meetings Mrs Roosevelt spoke out whenever an idea caught her imagination Mrs Roosevelt served beer in the foyer at parties for the press. The favorite flowers of Bess Truman were talisman roses A keenly intelligent and well-educated person, Mrs. Truman knew her politics. Unsuspected by many in government, Mrs Truman entered into almost every decision the President made Mrs Truman was very conscious of economy in housekeeping In Mamie Eisenhower, the public saw a friendly and outgoing lady Mrs Eisenhower slept late and generally breakfasted in bed Mrs. Eisenhower never treated the White House as government property--it was hers Mrs Eisenhower took an interest in everything that happened in her staff's lives Lady Bird Johnson remained a very private person in the swirl of public activity An avid T V fan, Mrs Johnson never missed her favorite show, "Gunsmoke" Mrs Johnson was extremely well organized and mapped out every day in advance. When she was worried, Mrs Johnson often hummed a tune

<u>Scrambled Version</u>

Each of the first ladies made a special imprint upon the White House Lady Bird Johnson was extremely well-organized and mapped out every day in advance. At meetings Eleanor Roosevelt spoke out whenever an idea caught her imagination. Mamie Eisenhower slept late and generally breakfasted in bed. When she was worried, Mrs. Johnson often hummed a tune A keenly intelligent and well-educated person, Bess Truman knew her politics. Mrs. Eisenhower never treated the White House as government property--it was hers Mrs. Roosevelt believed in physical exercise, and encouraged her staff to do calisthenics. An avid T.V. fan, Mrs Johnson never missed her favorite show, "Gunsmoke" Unsuspected by many in government, Mrs. Truman entered into almost every decision the President made. Mrs. Roosevelt's life was filled with visitors from early morning until late at night. The favorite flowers of Mrs. Truman were talisman roses Mrs Eisenhower took an interest in everything that happened in her staff's lives Mrs. Roosevelt served beer in the foyer at parties for the press. In Mrs Eisenhower, the public saw a friendly and outgoing lady. Mrs. Johnson remained a very private person in the swirl of public activity Mrs. Truman was very conscious of economy in housekeeping.

Table 8

Normal and Scrambled Passage Comprehension·
Mean Recall Scores and Reading Time in Seconds

		Normal Text		Scrambled Text	
Condition	Measure	High Ability	Low Ability	High Ability	Low Ability
Listening:	Recall	.25	.20	19	.19
Sentence-by-Sentence Reading	Recall	.35	.26	.34	.29
	Reading Time	155	222	175	252
Whole-Passage Reading	Recall	.28	.17	.21	.14
	Reading Time	74	70	79	72

In the listening experiment, the rate of presentation was controlled by the speaker, not by the listener. If the less skilled individual were not able to comprehend fast enough, we would expect him not to recall as much of the passages as the skilled people. Since the normal rate is slow enough for most people, including our not-so-poor less skilled readers, to understand at least at a low level, one might not expect dramatic differences in low-level comprehension of individual sentences. What should be more problematic is the level of understanding that comes from integrating sentences into a complete patterned message. Even the skilled readers may not have had time to sort out the scrambled passage representation. Thus, we would expect all subjects to have low-level comprehension for the scrambled passages. Indeed, skilled and less skilled readers had low and equal scrambled passage recall. For normal passages, deeper comprehension is easily possible. Here, the faster comprehension speed of skilled subjects should allow them a deeper level of comprehension and thus a better memory than the less skilled subjects, given the limited study time available. Indeed, skilled readers recalled significantly more of the normal passage propositions than of the scrambled passages, $F(1,36) = 5.13$, $p = .03$, while the less skilled group stayed at a uniformly low level.

Experiment 2 eliminated the time problem by giving subjects as long as they wanted to read each sentence. In this situation, the less skilled person should take longer to read a passage than the more expert reader, but there should not be as much difference in the recall patterns. Further, if the skilled and less skilled readers are doing the same things at different rates, there should be no difference in their distributions of reading time on differing sentences of the stories. Some sentences will be harder than others and thus take longer to read, but this should be true both for good and for poor readers.

The actual results are almost as expected. There was no difference between normal and scrambled passage recall for either high skill or low skill readers, F's < 1. However, skilled readers recalled more overall, $F(1,32) = 4.14$ (the critical value of this statistic for $\alpha = .05$ is 4.15), means = 35% vs. 27%. This recall difference may be due to retrieval problems rather than comprehension problems (cf. Royer, Hambleton, & Cadorette, Note 7). Such a conclusion is reinforced by the results of a clustering analysis of the normal passage recalls. The correlation between interproposition distances in the recall protocols and in the original passages was .59 for the good readers and .54 for the less skilled group, not significantly different. Thus, both groups are achieving the same level of understanding of the passage structure.

The reading time results were also as predicted. Skilled readers averaged 155 seconds to read their two normal passages and 13% longer (175 seconds) to read the scrambled passages. Less skilled readers took 222 seconds for normal passages and 14% longer (252 seconds) to read the scrambled passaged (both ability and normal/scrambled effects were significant, p's $< .028$). Less skilled readers took about 40% longer to do almost as well.

To analyze the individual sentence reading patterns, we normalized each subject's reading time for the individual sentences relative to his own mean and standard deviation. This removes any effect of one person being a fixed constant percentage faster than another, but it preserves the patterns of which sentences particular subjects spent more time on. We then performed an analysis of variance on the normalized sentence reading times. There were no interactions (the main effect of ability is made null by the normalization) of ability with any other factor, $F \leq 1.04$. (This same type of result was found for sentence recall frequencies in Berger, 1975, cited above.) There were, of course, effects of stories, normal/scrambled, and sentences within stories, p's $< .001$.

With respect to reading, both of these experiments are somewhat unrealistic since they involve either listening to or reading text in very small units. Therefore, a third experiment was carried out presenting the whole passage on a single sheet to be read through once, self-paced. Here, we should see a combination of effects depending upon whether less skilled readers will take the extra reading time they need when the choice is less salient between finishing the comprehension of one sentence and going on to the next. This time, there was a significant ability effect, with skilled subjects recalling 23% and less skilled subjected 14% ($p < .001$). There was also a normal/scrambled effect, with normal recall averaging 21% compared to 14% for scrambled ($p = .003$). There was no difference between skilled and less skilled subjects in overall reading time, $F < 1$. In contrast to the second experiment, there was also a difference in the passage structuring measure: .61 for the high group and .37 for the low ($p < .05$). If the speed-completeness tradeoff is responsible for these differences, then there should be less difference in reading times for the third experiment. As shown in Table 8, this is true. Less skilled readers took insignificantly less time to read the passages.

None of these experiments is a strong test of any of the issues raised. Overall, however, we think they imply that significant sources of individual differences may be more quantitative than qualitative. People are generally sensitive to information structure, foregrounding, and thematization and to sentence and clause boundaries. They tend to remember the same sorts of things after listening to or reading a passage. In general, there does not seem to be evidence for individual differences in sensitivity to S-structure or T-structure per se. However, individuals seem to differ in rate of discourse encoding and memory. The role of discourse structure may become salient only in the case of severe processing overload, which we have not approached in these experiments.

What Is Different between Good and Poor Readers?

While we have found no strategy differences between high and low skill individuals, it is indeed possible that such differences exist. However, it is certainly clear to us that these groups have pervasive differences in efficiency. These differences may well affect the utility of some strategies, but that is a separate matter. Our purpose in the remainder of the present paper is to discuss the processing rate differences we have reported so far, to show how coding speed differences may be the cause of the strange pattern of results on immediate memory span in skilled and less skilled readers, and to show how slow coding speed may play a role in higher-level comprehension components.

Coding Speed and Short-Term Memory

Are there STM differences? In a sense, our conclusions for discourse comprehension skill are similar to those advanced by Huttenlocher and Burke (1976) with respect to short-term memory span.

After investigating the existing literature extensively and performing additional experiments, Huttenlocher and Burke concluded that developmental differences in short-term memory span were due primarily to process factors rather than strategic differences. In fact, their proposed factors of facility for encoding incoming information and ability to preserve order information certainly overlap our hypothesized process difference in verbal coding speed. A more recent paper (Chi, 1976) develops a similar argument in much more detail and argues that STM capacity differences are functional and not (in general) due to differences in the underlying number of STM "slots."

One might argue that poor readers have less functional STM capacity, but that does not seem to be the case entirely. As we noted before, skilled and less skilled readers do not differ in the probe digit task (Perfetti & Goldman, 1976) which is a paradigmatic STM task (Waugh & Norman, 1965). There are differences between adults of high and medium quantitative aptitude in short term memory capacity measured from the Atkinson and Shiffrin (1968) continuous paired-associate task (Hunt, Frost, & Lunneborg, 1973). However, verbal aptitude, which seems more directly related to reading ability, does not correlate with the STM measure.

There are a series of studies that have found short-term memory differences between skilled and less skilled readers, but there are also other studies that have not found a difference (Guyer & Friedman, 1975; Hunt, Lunneborg, & Lewis, 1975. Valtin, 1973). One clue to the reason for this [illegible] unanimity was supplied by Valtin (1973), who found that skilled and less skilled elementary-school readers do not differ on digit span but do differ on short-term memory for similar sounding words. More complete adult data reported by Hunt et al. (1973) make the same point. High-verbal college students do better on an ordered short-term retention test (Peterson task) than average students, but there is no difference noted in auditory digit span.

There are also some more indirect sources of evidence that there is no <u>general</u> STM capacity shortage in poor readers. Factor analyses of intelligence subtests show that digit span does not load highly on the same factors as verbal comprehension (Case & Globerson, 1974; Hunt et al., 1975). Further, we know that (a) the probe digit test of STM does not differentiate good readers (Perfetti & Goldman, 1976), and (b) probe <u>letter-string</u> memory accounts for about half the variance in digit span (Lyon, 1975). It seems reasonable to infer from (b) that: (c) probe <u>digit-string</u> memory performance should account for at least half the variance in digit span. We conclude from (a) and (c) that digit span does not distinguish the skilled reader from the less skilled.

The experiments we have been able to discover that do show span effects seem to be explainable in terms of verbal coding efficiency factors. There is, for example, a study by Farnham-Diggory and Gregg (1975) which found span differences between 10-year-old good and poor readers on both visual and auditory tests. However, study did not use the standard digit span method. Rather, it presents groups of four letters sampled <u>with</u> replacement from the set [B, K, M, S]. Further, the group differences consisted of differential release from proactive inhibition (PI) when, after 10 trials, there was a switch from auditory to visual presentation or vice versa. On the early trials, there was no clear reading group difference. Leslie (1975) found a similar effect in immediate ordered recall of pictures (same pictures over trials). This suggests that reports of STM span differences may really be reports of differential PI or release from PI. This conclusion is bolstered by differences between high and average verbal ability adults in semantic-shift release from proactive interference shown by Hunt et al. (1973, report of Nix's experiment).

Another study (Rizzo, 1939) found letter-string span differences between skilled and less skilled readers at some ages on both tachistoscopic simultaneous visual span and the more common sequential-presentation, normal-exposure paradigm. The tachistoscopic finding came from an experiment with superspan displays (nine letters), and it corresponds to a similar finding in adult fast vs. slow readers (Jackson & McClelland, 1975), which also failed to find any digit span difference using the standard procedures. The non-tachistoscopic effects came from tests in which a superspan number of letters were presented at a slow rate (17 seconds for nine letters). The combination of superspan presentation and slow rate may have made the test very sensitive to complex coding speed differences. Further, the effects were rather small.

Another span-type task in which skilled and less skilled readers differ is immediate memory for sequences of Vanderplas-Garvin figures. Noelker and Schumsky (1973) found that even though recognition memory for the random shapes was equal in skilled and less skilled readers, less skilled readers were less able to sort the shapes into an ordering they had just been shown. From this, they argued that less skilled readers are less able to represent order. Examination of their task reveals that verbal labeling may play a major role in the representation of the shapes in STM. The massive amount of information in a random figure must be chunked (given a name or symbol representation) in order to "fit" in STM. Thus, the Noelker-Schumsky task may be testing ordered span for sets of (potentially) complex verbal description.

If the standard sequential testing procedure is used, there does not seem to be a correlation between immediate memory span and reading ability. For example, the Auditory Sequencing Test of the Illinois Test of Psycholinguistic Abilities, in which digits are presented at a 2-second rate, does not correlate with reading ability in a nonretarded population (Guyer & Friedman, 1975; Kass, 1962). The Visual Sequencing Test of the ITPA does show occasional relationships with reading ability (Kass, 1962), but there have also been null findings (Guyer & Friedman, 1975, see also various comments in Bateman, 1965). The problem here is that the test uses visual forms which may be difficult to verbally code quickly, as noted in our discussion of Noelker and Schumsky above.

It is also possible to find digit span differences between skilled and less skilled readers if IQ is not controlled. For example, Belmont and Birch (1966) found that when IQ is not controlled, skilled and less skilled readers may show differences on the Wechsler Intelligence Scale for Children (WISC) digit span subtest, but when IQ is controlled (by matching total WISC IQ) even the poorest readers do not show deficits on the digit span subtest. Rather, they are low on the information, arithmetic, and vocabulary subtests only.

Overall, we can say that poor readers who are not severely retarded do not have a general deficit in STM capacity. However, this does not mean that they have adequate functional STM capacity in verbal comprehension contexts. A Thurstonian view of STM abilities may be in order. The presence of enough temporary "storage space" can be thought of as a general factor, while performance characteristics more specific to the verbal processing domain would influence effective STM in message comprehension, and subject-specific coding skills would play a role in comprehension of messages on that subject.

One final study adds interesting perspective to the issue of memory function differences. Cummings and Faw (1976) compared two groups of children who were the same age, an average of 10.5 years, and had equal mean IQs but greatly different scores on the reading section of the California Achievement Test. They tested these children on short-term memory for a sequence of six symbols from a pool of 15, including star, circle, ampersand, etc. The task was a same/different judgment procedure with either simultaneous presentation of two sequences or a delay of one or six seconds between them. Skilled and less skilled readers were equally correct on judgments of simultaneous strings. They were also equally correct in making the same response for the delay conditions. However, good readers were more accurate than less skilled readers on different trials when there was a delay between strings.

These results are consistent with our coding speed model for STM differences between skilled and less skilled readers, but they suggest some interesting complexities. First of all, some tasks, like the Cummings and Faw simultaneous condition, have adequate external memory support. In addition, they can be performed with a very quick check to see if there is obvious difference between strings. Such a check is like the first stage decision in the Atkinson and Juola (1973) model. Same judgments, even after a delay, may still be done at this global "familiarity" level. F a the case of different judgments, some sort of item-by-item search of the symbol names seems to be required. This search loads STM by requiring that good traces for the first string remain available and by being a more complex decision task. The person whose verbal coding speed is slower (cf. Perfetti & Lesgold, Note 2) will be less able to rehearse (and thereby maintain) his STM contents; he will therefore do more poorly. Thus, STM differences may be somewhat elusive in their effects on comprehension performance. Part of the time, even a "faded" STM will suffice (as in the Cummings-Faw delayed-same conditions). However, part of the time, several precise codings will need to be retained in STM simultaneously. Here the slow coder, with resultant lesser functional STM, will have problems.

Implications of STM processing differences. Suppose that we accept the hypothesis that coding speed (time to retrieve a name as well as time to retrieve semantic or articulatory information associated with a name) is the source of STM differences between good and poor comprehenders. Our next task, then, is to explore some of the ways in which a less effective STM might manifest itself and to relate these to existing demonstrations of performance differences between good and poor readers. We will explore two basic cl sses of STM problems: (a) hysteresis, and (b) specificity and ordering deficiencies.

By hysteresis, we mean an inability of STM coding mechanisms to keep up with the demands placed on them. This means either that STM availability will be temporally out of phase with STM input or that some input and output demands on STM will fail to get processed. A useful analogy is to the slow assembly line worker. As the worker gets out of phase with the line, he starts to be less efficient in his movements, thus being slowed even more. Finally, some of the items on the line slip by without his contribution being completed. Similarly, in comprehension there are recurrent input and output events for short-term memory. The slow coder will, we argue, fall behind in the cycle of comprehension events, revert to less efficient patterning of the various comprehension process components, and finally fail to comprehend some of the discourse. He must either "stop the assembly line," as in the sentence-by-sentence passage reading experiment reported above, or fail to complete an implicit agenda of comprehension processes.

The hysteresis hypothesis suggests that the poor comprehender should be more affected by interference (from old traces he did not have time to erase) and slower at encoding new information. This may account for some data of Hunt, Lunneborg, and Lewis (1975) on high vs. low verbal ability adults. Adults of lower verbal ability were slower at encoding information from sentences, such as "The star is above the plus," than were subjects of high verbal ability. They also did less well in Sperling-type tachistoscopic reports which depend upon encoding the display fast before it decays in the sensory system (see also Jackson & McClelland, 1975). Further, they were less able to sort information presented simultaneously to the two ears into category groupings. Finally, the less skilled readers showed little or no release from PI, as mentioned in our discussion of the Farnham-Diggory and Gregg (1975) results above.

There is other evidence that is consistent with the hysteresis hypothesis. Katz and Deutsch (1963) tested first, third, and fifth graders in a simple decision task (press button one for red light or low tone, button two for green light or high tone). The interesting data they collected was on same-mode vs. different-mode trials. A same-mode trial was one in which the signal (light or tone) was of the same modality as on the previous trial. All subjects had faster times on same-mode trials, but the difference between same-mode and different-mode response times was greater for less skilled readers, especially in first and third grade. This suggests that those children were slower at reconfiguring their short-term memories from the light decision scheme to the tone decision scheme and back.

Experiments by Spring (Spring & Capps, 1974; Spring & Farmer, 1975) also support the hysteresis hypothesis. He showed that (a) poor readers (elementary school) are slower at naming digits, colors, and pictures of common objects; (b) digit naming speed wholly accounts for tachistoscopic span effects, and (c) digit naming speed accounts for most of the variance in an ordered STM task.

An alternative but related view of the STM problems of less skilled comprehenders is the Specificity/Ordering Hypothesis. It argues that the STM codes of less skilled comprehenders are less specific and less complete than those of good comprehenders, making them less retrievable and (depending upon what the mechanisms of order encoding are) less accurately ordered. This Specificity/Ordering Hypothesis is also well supported. For example, the Noelker and Schumsky (1973) study cited above showed that 9-year-old poor readers, matched for IQ, do worse than good readers on recalling the order of series of Vanderplas-Garvin figures. This difference is dramatic in contrast to almost equal ability to recognize which forms were in the series. Less skilled readers were also less able to reconstruct linear arrangement of black and white circles, a task which is almost a pure measure of short-term ordering retention. The data from Farnham-Diggory and Gregg (1975) are also relevant because the constant and small stimulus set they used turned their task into an order retention task.

Experiments which claim to show differences in ordering ability may, in fact, be showing that skilled comprehenders suffer the same degradation of order information over time as less skilled comprehenders do, but that they are more able (in the limited time available) to alter encodings to resist the interfering effects of previous related encodings. For example, both the Farnham-Diggory and Gregg (1975) and the Hunt et al. (1973) studies found essentially equal rates of accumulation of proactive inhibition for good and poor readers. The difference is in ability to use new coding potential to effect release from PI. There are two ways this could happen.

One possibility is that the skilled subjects know more effective coding schemes. This possibility is supported by the work of Mohan (1975) showing that children of below-average reading skill (ages 7 and 11) make more errors of perceptual confusion (in proportion to total errors) in memory span tasks than do more skilled children. This was true for both visual confusions (E with F) and auditory confusions (B with P). Presumably, the skilled readers either use more abstract codes for the letters or, more probably, they encode information about letter clusters rather than single letters. The other possibility is that encoding operations that are required to take advantage of potential "release from PI" cannot be completed by the less skilled comprehender in the time available.

The explanation for and demonstrations of greater STM limitations in less skilled readers that we have discussed are all variations on the same theme. Given temporal restrictions on the extent of encoding into STM, later retrieval of accurate information from STM will depend on the extent to which, in the time available, an encoding was found that was accurate and complete. The code must also be tied to specific long-term memories clearly enough so that it does not prompt the wrong decoding at retrieval time. Thus, there is a strong interaction between how much can be temporarily kept in STM and how well learned specific contents of LTM are.

Reading is not the only skill for which the relative roles of short- and long-term memory have been confused. It was traditional for people to assume that the master chess player was better at chess because he could think ahead many moves. Mentally rehearsing a series of even three or four moves becomes a major STM feat because of the combinatorial explosion of possible moves and countermoves. There now is evidence that the master chess player thinks no further ahead than less skilled players. Instead, the master player knows 10,000 to 100,000 board position patterns and what to do in each case (Chase & Simon, 1973; de Groot, 1965).

The skilled language comprehender may be skilled for similar reasons. Perhaps for the skilled comprehender, discourse macro-structures, grammatical forms, and lexical information are well learned, both in quality and in number. Hence, all of the specifics of a given message are quickly and accurately encoded. In the Thurstonian model we proposed above, it is not the general factor of STM size that we emphasize but the more specific factor of verbal coding. We suggest that, aside from those individuals who suffer intellectual retardation, most of those who are poor specifically in verbal comprehension are simply not as practiced in the skills of verbal encoding and decoding (as has been suggested in slightly different form by LaBerge & Samuels, 1974; and Kolers, 1975).

This leads to the suggestion that overlearning (drill and practice) is one means of overcoming the STM bottleneck. This conclusion has several sources of support. First, developmental differences in choice reaction time are to be found only for non-overlearned tasks (cf. Wickens, 1974). If the assumption is valid that individual differences are found primarily in processing characteristics that vary with age, then we would expect that either lack of overlearning (automation) is a sufficient cause of verbal processing deficiency or, at least, that is is a necessary factor for such deficiencies to be able to manifest themselves. There is also a little data (Perfetti & Hogaboam, Note 8) showing that for at least one task (vocalization latency), training can decrease observed differences between skilled and less skilled readers.

The Effects of Slow Coding on Comprehension

In this section, we will discuss how slower verbal coding specifically affects discourse comprehension. Again we assume that both verbal encoding and verbal decoding are slower and less efficient in less skilled comprehenders, even though our evidence is incomplete. It is clear that such coding speed differences are involved in apprehension of the individual words one reads or hears, and we would like to offer a theoretical description of the role of verbal coding in deeper aspects of comprehension.

Verbal codes (words) are an essential factor in overcoming the bottleneck on thought imposed by a limited conscious (short-term) memory. This is not a new idea but we are only starting to realize its implications. The bottleneck problems are nicely discussed by Anderson and Bower (1973, Chapter 2) when they consider the paradox of Mill's house. In a simple associative memory, as James Mill pointed out, a name is associated with a concept which is itself associated with other concepts which are associated with other concepts, etc. If automatic association is the means whereby memories are retrieved, then seeing the word house will cause us to think not only of houses, but also of bricks, of boards, of wood, of trees, of forests, etc. However, if the short-term memory bottleneck means anything at all, it must mean that we cannot think about all that at one time. What then is the mechanism for delimiting how much detail and which related knowledge is in conscious memory when a particular concept is being thought about?

One principle that has been useful in cognitive theory is the type-token distinction (Simon & Feigenbaum, 1964). Any particular collection of memory associations can connect with one or more copies or tokens of the name of a concept but not to the concept itself. Thus, the various associations that involve the same concept in different contexts are not directly connected by simple associative pathways. The type-token distinction is maintained in all current network models of memory.

In a memory with the type-token distinction, the act of retrieving the conceptual information associated with a name is a basic, recurrent part of comprehension. Ideas are represented as structured relationships among names (or tokens) for other ideas. Any time that comprehension or thinking require any elaboration, extension, or qualification of a concept, those names (tokens) must be decoded--replaced by the concepts (types) for which they stand. If less skilled comprehenders are slower at retrieving the conceptual information associated with a name, then they should be slower not only in word identification but also in deeper levels of comprehension processing since it is hypothesized that these levels, too, involve decoding.

The schematic model of comprehension and memory proposed by Rumerhart and Ortony (in press) nicely illustrates this pervasiveness of verbal decoding. Their model represents human memory as consisting not of one big network but rather a collection of schemata. A schema is a relatively small bundle of information about a concept. For example, the schema for bank might include the information that a bank has the following properties:

1. People deposit money in accounts at the bank.
2. People cash checks at the bank.
3. People write checks on their bank accounts.
4. Banks issue loans.
5. Banks manage trusts.
6. Banks engage in merchant banking.

7. A bank is a building.

8. A bank is an institution.

Each of the underlined phrases represents concepts which would not only be named in the bank schema but which have schemas[5] for their definition as well. Thus, minimal understanding of bank requires retrieving the schema associated with that word. More detailed, deeper understanding requires retrieving the subschemas that are represented only nominally in the bank schema. This formulation gives a greater specificity of the notion of depth of encoding or elaboration. An idea is encoded deeply to the extent that it is represented by a tightly connected set of (tokens for or copies of) schemas.

Suppose that one is trying to encode a sentence into memory. Each word or structured group of words corresponds in general to a schema in memory. The lowest level of comprehension is that the schemas corresponding to each of the content words in the sentence being processed are simultaneously active. Higher levels of comprehension result from the tying together of the multiple schemas invoked by a sentence and from the elaboration of schemas by replacing names with subschemas.

Consider the task of comprehending and remembering a textual message. The task is to construct a working memory representation that (a) accounts for as many of the words and groups of words as possible: (b) is as interconnected as possible: and (c) is somewhat elaborated, especially with respect to the message's most central components. We will briefly sketch the sorts of processing that must go on in comprehending a text, but we must first introduce one more distinction.

To achieve consistency of usage within this volume, we joined our more modern colleagues in using this plural form rather than the classical "schemata." For reasons of pure pedantry, we retain "schema," repugnant as its borrowed spelling scheme may be.

So far, we have (following Rumelhart & Ortony) talked about schemas that are tied to a single word or group of words that is their name. However, in addition to these nominal schemas, there are also predicative schemas. These schemas have, in place of some of the slots that might contain names, free variables (in the sense of standard predicate logic) that can be bound to words in text and/or to the names of other concepts. These free variables are more or less what linguists have called cases (Fillmore, 1968). For example, consider the sentence:

(9) John saw his face in the mirror.

If there is a see in mirror schema, then presumably it has two free variables, the viewer and the object viewed. The first could be bound to John and the second to face.

There are, of course, restrictions on what names can bind a given free variable. For example, if there is a word in the sentence not otherwise bound that can be shown to be part of the viewer, it will be more likely than other sentence words to be bound to object viewed. There are restrictions on which nouns can be bound in what ways to a predicative schema just as there are linguistic rules of thumb (Fillmore, 1968) or formal rules (Anderson, 1971) for verb cases.

We can now consider how sentence 9 is comprehended. Presumably, the person hearing the sentence might bind each word to a different schema, but this is unlikely (unless word decoding is so attention demanding that only one word can be decoded and held in STM at a time). Probably, the see in mirror schema will be invoked if it is available for that person. That schema can account for (bind) all of the content words of the sentence. However, there is more to be understood in the sentence. A deeper level of comprehension would include some representation of the relationship between John and face, viz., that John is a person who has a face and that it is his face that he saw in the mirror. Figure 4 is a sketch of this level of comprehension. One could go deeper still, elaborating by adding into the working memory representation of the passage some of the schemas named in other schemas. Figure 5 shows an example in which face and mirror are elaborated by ties to the three additional schemas.

Suppose the person now saw a second sentence, such as:

(10) His eyes were bloodshot from the night before.

A minimal modification of Figure 5 to reflect some comprehension of this sentence might invoke the bloodshot schema and tie it to eyes; the cause schema might be bound to both the bloodshot schema and the sentence words the night before. Further depth of understanding would result from invoking some sort of profligacy schema to bind the night before.

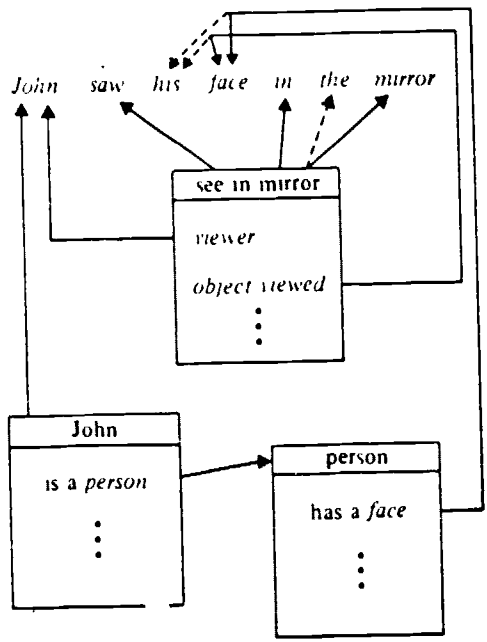

Figure 4 Comprehension of *John saw his face in the mirror* by invoking the *see in mirror* schema plus representation of *John* and *person*

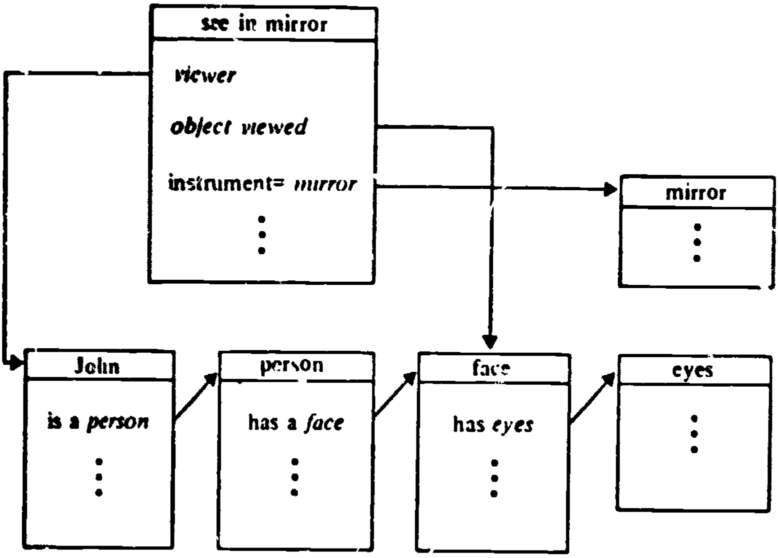

Figure 5 A slightly deeper level of comprehension for *John saw his face in the mirror* achieved by activating additional schemata

It is important to note some of the relationships between depth of processing of the first sentence and the level of processing required to process the second sentence to a given depth. There is a tradeoff. For example, elaboration of face to include eyes during the processing of the first sentence would make processing of the second sentence easier since the eyes schema would be ready in working memory to immediately bind the word eyes in the second sentence. On the other hand, too much elaboration of the first sentence would add excess baggage to the working memory representation of it, resulting in incorrect interpretation and/or lack of clarity. Note also how S-structure helps to segment the sentence into "bindable" units while T-structure helps to determine whether an appropriate schema is already active or whether a search of LTM is necessary.

The general dynamics of comprehension in such a schematic processor must depend heavily on certain processing capacities of the system into which it is embedded. Let us return to some of the capacity differences between skilled and less skilled comprehenders to see the implications for schematic comprehension process g.

The double whammy. There are two properties of less skilled readers that would make them peculiarly inefficient as comprehenders of the type just outlined. They are poor at verbal coding (i.e., they are slower at naming a word stimulus and at retrieving semantic information in response to a name; see Perfetti & Hogaboam, 1975a, Note 8). Also, they are not as good at retaining exact working information of sentences they hear during the period of time in which comprehension depend upon having working information available (Perfetti & Goldman, 1976). As we discussed above, these two properties may be different aspects of a single underlying problem.

It is exactly these two capacities that are critical to comprehension, as we (following Rumelhart & Ortony, in press) have outlined it. In order to be able to forget sentence wording without cost, the comprehender must have bound all important sentence words to schemata and interrelated those schemata to the point at which wording information is no longer needed to temporarily connect the pieces of meaning. The process of building a connected schematic representation depends heavily on the decoding of subschemata names in schemata and the invoking of those subschemata. But, poor readers are slow at name decoding; consequently, they should get less of the job finished in a given amount of time.

This agrees with our data in suggesting that it will take more time for less skilled readers to achieve a given depth of comprehension. Thus, when reading (or listening) is self-paced less skilled people should and do take longer. when it is limited for time, they should and do comprehend more poorly. This, in itself, is not too surprising. Indeed, reading speed is a favorite measure of reading ability. By our argument, though, some sort of "listening speed" measure should also work. Indeed, there is a bit of work existing that shows a strong relationship between reading and listening comprehension ability (Berger, 1975; Sticht, Note 9). Further, the data presented above agree pretty well with this expectation. The normal text was better comprehended by the good readers in the listening experiment while the scrambled text, which presumably could not be quickly processed to a deep level by either group, showed no differences between them.

When we consider the less skilled comprehender's poorer memory for sentence wording while reading or listening, we see easily how this compounds his difficulties. The poor reader is slower at getting to the point in the comprehension process beyond which exact wording is not needed, but he is also poorer at retaining exact wording. Thus, he is confronted with a double whammy--slower processing and lower tolerance (in terms of working memory), both of which combine to create more processing needs than might otherwise exist.[6]

Having made this theoretical overview, we now must give a word of caution. First of all, there is not much data to support the conclusions to our argument, though the premises of verbal coding and memory differences are supported. Further, while the schematic theory which we have extended to the individual differences question is consistent with some related experimental findings (see Rumelhart & Ortony, in press), there is clearly a need for increased identifiability of its components with possible experimental measures so that the claims made here are more testable. The work of Frederiksen (1975b, Note 10) and Kintsch (1974, Kintsch et al., 1975) will, we believe, contribute to this.

A second problem is treated in another paper of ours (Perfetti & Lesgold, Note 2). Specifically, we do not know the direction of cause

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[6] The term double whammy originated in the L'il Abner © comic strips of Al Capp to refer to a devastating punitive event.

in the above scenario. While we have shown that name coding skill is essential to comprehension, we have not shown that the causal relations run only in one direction. It is exactly because encoding and decoding of names is such a basic part of comprehension that practice in comprehension may be responsible for increases in coding speed. Thus, we cannot say for certain that skilled readers get to be skilled by practicing naming responses or that this will make less skilled readers better. However, direct test of the direction of causation is difficult and may not be the best way to proceed (Perfetti & Lesgold, Note 2). Elaboration of both the component processes of discourse comprehension and the individual differences in those processes will probably be more fruitful.

Summary

In this paper, we have tried to relate individual differences in discourse comprehension to the following principles. First, sentence wording must be represented and segmented, at least in part. Second, words and wording segments must be bound by schemata from a long-term lexicon and/or from currently foregrounded portions of the representation for the earlier parts of the discourse. Third, the new sentence's representation must be tied to that of earlier discourse portions if that has not been the automatic consequence of the previous step. Fourth, but not necessarily last in the order of processing, the current foreground may have to be adjusted in light of the current sentence's meaning.

Returning to Figure 2, we again point out the major role that short-term memory plays in the discourse comprehension process. It must contain any sentence wording and segmentation information in addition to indexing foregrounded information. There are two important points to note. One is that all of this short-term memory content must change rapidly. For example, if one is reading text at 300 words per minute and the text consists of single-proposition, five-word sentences, then STM for exact wording would turn over every second! The other point to note is that S-structure information can speed the segmentation and lexical/schematic binding processes and the T-structure can facilitate those binding processes and also the modification of the foreground.

The findings we have presented or cited, showing that coding of wording information into STM is slower and less complete in the less skilled comprehender, are made more salient by the relatively non-controversial recitation above of the major components of ongoing discourse comprehension. It is clear that STM can become a bottleneck for higher-level processing solely because of the speed of coding into and out of STM. Given the lack of findings so far to suggest any major strategy differences in children or adults who are alike in overall cognitive development but different in reading achievement, we suspect that further study of the STM role in discourse comprehension will be fruitful.

Even though we have found no evidence of differential sensitivity to S-structure or T-structure, it may well be that S-structure and especially T-structure can be manipulated in ways that decrease the STM load on less skilled comprehenders. Consequently, it is important to continue the psycholinguistic study of these structures even though no structure is known to present a direct problem to less skilled comprehenders. Work on S-structure and T-structure will also help to produce measurement procedures that provide a greater identifiability of theory with observed performance.

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