

Syntactic comprehension in young poor readers

SUZANNE T. SMITH

Neurolinguistics Laboratory, Massachusetts General Hospital

PAUL MACARUSO, DONALD SHANKWEILER,
and STEPHEN CRAIN

University of Connecticut and Haskins Laboratories

ADDRESS FOR CORRESPONDENCE

Suzanne T. Smith, MGH Neurolinguistics Laboratory, 15 River Street, Boston, MA 02108

ABSTRACT

Children with specific reading disability fail to understand some complex spoken sentences as well as good readers. This investigation sought to identify the source of poor readers' comprehension difficulties. Second-grade good and poor readers were tested on spoken sentences with restrictive relative clauses in two experiments designed to minimize demands on working memory. The methodological innovations resulted in a high level of performance by both reader groups, demonstrating knowledge of relative clause structure. The poor readers' performance closely paralleled that of the good readers both in pattern of errors and in awareness of the pragmatic aspects of relative clauses. The findings suggest that limitations in processing account for comprehension difficulties displayed by some poor readers in previous investigations.

This study investigates the syntactic abilities of poor readers — children who show a marked disparity between their measured level of reading ability and the level of performance that might be expected in view of their intelligence and opportunities for instruction. Much research on children with specific reading disability finds the source of their problems in the language domain, not in visual perception or general analytic ability (Lieberman, 1983; Perfetti, 1985; Vellutino, 1979). Within the language domain, the research literature indicates that the difficulties poor readers display are usually associated with some aspects of phonological processing.¹

Recently several investigations have raised the possibility that poor readers' limitations may include other components of language processing. For example, it has been found that poor readers fail to comprehend complex spoken sentences accurately in some circumstances. These findings have led some researchers to question whether poor readers have mastered all of the complex syntactic properties of the adult grammatical system.² However, it is important to appreciate that another explanation for their sentence processing difficulties can be given. It is possible that the problems poor readers have in comprehending sentences may ultimately derive from the same limi-

tation in processing that accounts for their failures on lower-level tasks involving the phonology. The present research seeks to gain a better understanding of the basis of poor readers' failures in sentence comprehension by testing between these competing possibilities.

The first hypothesis, which we will call the *syntactic lag hypothesis*, is a natural outgrowth of a large body of research on language acquisition that suggests that complex syntactic structures are late to develop. In this view, language is assumed to be acquired in a stagelike progression from simple to complex structures, with complex structures mastered later in the course of language acquisition (see, Crain & Shankweiler, 1988, for further elaboration). Young poor readers are unable to comprehend certain syntactic structures as well as good readers because poor readers are considered to be developmentally delayed in the acquisition of syntactic knowledge (see, e.g., Byrne, 1981; Fletcher, Satz, & Scholes, 1981; Stein, Cairns, & Zurif, 1984). The syntactic lag hypothesis is buttressed by findings indicating that, in samples of spoken language, poor readers tend not to use complex sentence structures, and their utterances often contain morphosyntactic errors (de Hirsch, Jansky, & Langford, 1966; Fry, Johnson, & Muehl, 1970; Morice & Slaghuis, 1985; Vogel, 1975). Further evidence shows that poor readers have difficulties with metalinguistic tasks such as correcting or explaining syntactically anomalous sentences (Bohannon, Warren-Leubecker, & Hepler, 1984; Bowey, 1986; Forrest-Pressley & Waller, 1984; Fowler, in press; Menyuk & Flood, 1981).

For an adherent to the syntactic lag hypothesis, the reading comprehension failures of poor readers cannot be blamed on decoding difficulties alone, since on this account, poor readers have, in addition to their problems at the word level, a syntactic immaturity that predisposes them to difficulties in understanding some sentences. Moreover, the difficulties that poor readers display in comprehending spoken sentences cannot be a result of their inadequacies in decoding. Thus, to account for poor readers' difficulties in reading and in comprehending spoken sentences with complex syntactic structures, proponents of the syntactic lag hypothesis must invoke deficiencies in at least two components of the language system: the phonology and the syntax. On one hand, a deficit in phonological processing must be invoked to account for the weak decoding skills that are so often present in poor readers. On the other, their impaired sentence comprehension would reflect jointly the phonological processing problems and a delay in the acquisition of syntactic knowledge.

In contrast to this dual deficit account of poor readers' reading and comprehension difficulties, an alternative hypothesis explains both word-level and sentence-level problems as the result of the same underlying deficit. In this view, which we call the *processing limitation hypothesis*, all of the poor readers' language-related difficulties are considered to derive from a limitation in phonological processing. In other words, this hypothesis maintains that poor readers' performance deficits at higher levels of language processing are symptoms of an underlying phonological deficit (Lieberman & Shankweiler, 1985; Mann, Shankweiler, & Smith, 1984; Perfetti, 1985; Shankweiler & Crain, 1986; Stanovich, 1986). In addition to creating diffi-

culties in decoding, the phonological deficit gives rise to comprehension problems, both in reading and spoken language, by exhausting the resources of verbal working memory which must be shared by lower-level and higher-level language processes.

Evidence for the link between phonological processing and verbal working memory is based on research demonstrating that short-term memory for verbal material relies upon phonological coding (Conrad, 1964, 1972; Conrad & Hull, 1964; Crowder, 1978) and research indicating that poor readers show selective impairment on tests of verbal memory. Poor readers' impaired memory for verbal material has been demonstrated for a wide range of stimuli including nonsense syllables (Liberman, Mann, Shankweiler, & Werfelman, 1982), unrelated words (Mann, Liberman, & Shankweiler, 1980; Smith, Mann, & Shankweiler, 1986), and sentences (Mann et al., 1984; Mattis, French, & Rapin, 1975; Roit, 1980; Shankweiler, Smith, & Mann, 1984; Weinstein & Rabinovitch, 1971; Wiig & Roach, 1975). In contrast, memory for a variety of nonverbal stimuli is unimpaired (Liberman et al., 1982; Nelson & Warrington, 1980; Vellutino, Pruzek, Steger, & Meshoulam, 1973).

With regard to sentence processing, the processing limitation hypothesis supposes that because information in language is conveyed sequentially, phonological coding in verbal working memory is needed to retain linguistic information temporarily in verbatim phonological form while syntactic and semantic relations are determined. This approach advances the view that all the symptoms of reading disability arise from an underlying difficulty in phonological processing, thus eschewing the proposal that poor readers are delayed in the acquisition of syntactic knowledge. The processing limitation hypothesis predicts that poor readers, because of their phonological processing deficit, will be unable to fully exploit their syntactic knowledge and will encounter difficulties with just those sentences that exceed the resources of verbal working memory. By contrast, on sentences that are less taxing of those resources, their performance level should approximate that of good readers.

To summarize, the syntactic lag hypothesis and the processing limitation hypothesis present sharply contrasting explanations of poor readers' problems in sentence comprehension. Since spoken language comprehension surely sets an upper bound on the ability to comprehend sentences in reading, it is imperative to reach a diagnosis of poor readers' comprehension problems. Neither of the hypotheses under consideration can be rejected at present. The aim of this research is to discover which one provides the best account of poor readers' problems in spoken-language comprehension. In the following experiments, the relative clause was chosen as a test case for evaluating the two hypotheses.

COMPREHENSION OF RELATIVE CLAUSES

Several studies of language acquisition have found that relative clauses emerge late in the course of normal language development (see Sheldon, 1974; Tavakolian, 1981). This has led proponents of both hypotheses to ask whether reading-disabled children are inferior in performance to age-

matched good readers in comprehension of sentences containing these structures. Before we review studies that address this question, some preliminary comments are in order about the properties of relative clauses.

Relative clauses are of special interest because of their syntactic and semantic/pragmatic properties. Four types of relative clause sentences are illustrated: these are distinguished by a two-letter code indicating the noun phrase, subject or object, in the main clause that bears the relative clause and the site of the superficially empty noun phrase in the relative clause. For instance, in the OS sentence (3) the object noun phrase of the main clause is modified by a relative clause that lacks an overt noun phrase in subject position. The empty noun phrase is marked by "—" in these examples.

- (1) SS The girl who — pushed the boy tickled the clown.
- (2) SO The boy who the girl pushed — tickled the clown.
- (3) OS The girl pushed the boy who — tickled the clown.
- (4) OO The boy pushed the girl who the clown tickled —.

In relative clause sentences, coreference must be established between the missing noun phrase in the relative clause and a controlling noun phrase in the main clause. Coreference relations are governed by structural constraints involving the notion of *c-command*. These constraints rule out certain coreference possibilities and therefore restrict the semantic interpretations that a sentence can be assigned.

In addition, relative clauses serve several pragmatic functions. One pragmatic function distinguishes restrictive and nonrestrictive relative clauses. Restrictive relatives act to specify a particular subset from a larger set of items. This means that restrictive relatives are used felicitously in situations in which there is a group of objects corresponding to the head noun phrase of the relative clause. For example, in sentence (5a) the relative clause "that had a bow around its neck" acts to pick out a particular teddy bear from a group of teddy bears. In contrast, nonrestrictive relative clauses function merely to comment upon the noun phrases they modify, not to further delimit them. Sentence (5b) contains a nonrestrictive relative clause "which had a bow around its neck." In this case, the relative clause serves only as a further comment about the one teddy bear in the context, namely that it had a bow around its neck.

- (5a) The boy was holding the teddy bear that had a bow around its neck.
- (5b) The boy was holding the teddy bear, which had a bow around its neck.

Having reviewed the relevant properties of relative clauses, we turn now to studies of their comprehension by good and poor readers. Several recent investigations have indicated impaired performance by reading-disabled children on various forms of relative clause sentences (Byrne, 1981; Goldsmith, 1980; Mann et al., 1984; Stein et al., 1984). The findings have generally been regarded as supporting the syntactic lag hypothesis. However, a dissenting note was sounded at the conclusion of the study by Mann et al. (1984), in which two of the present writers were coinvestigators.

In the Mann et al. (1984) study, third-grade good and poor readers were tested for comprehension and (on another occasion) for repetition of the same relative clause sentences. On the comprehension test, the poor readers made more errors than the good readers; however, both reader groups made similar types of errors and there was no interaction between reader group and sentence type. On the repetition task, too, the poor readers performed less accurately than the good readers. Thus, the poor readers were impaired in both comprehension and repetition of test sentences, but their errors, although more numerous, were similar to those of the good readers. Mann et al. maintained that the higher error rate for the poor readers can be explained as stemming from their limitations in the effective use of phonological structure in the service of verbal working memory.

Giving credence to poor readers' limitations in processing, the present study sought to identify ways to reduce the processing load in order to permit them to demonstrate their knowledge of relative clauses. Until this step is taken, the source of poor readers' observed comprehension failures remains an open question: either the syntactic lag hypothesis or the processing limitation hypothesis could explain some portion of the findings. In planning the present study, several potential sources of processing difficulty that may have adversely affected poor readers' performance in earlier research were identified, and steps were taken to minimize the difficulties. Success in reducing or eliminating the performance gap between good and poor readers would constitute support for the processing limitation hypothesis. We now describe the factors that may affect difficulty of processing and the steps that were initiated to control these factors in the present study.

First, most of the previous studies of relative clauses failed to take into account their pragmatic functions. In other words, these studies did not meet the *felicity conditions* associated with the use of restrictive relative clauses. For example, the Mann et al. (1984) study used an object manipulation test in which the stimulus array consisted of one token of an object for each noun phrase. As discussed earlier, restrictive relative clauses are used felicitously only in contexts which establish a set of objects corresponding to the head noun phrase of the relative clause. To satisfy this pragmatic condition, more than a single item corresponding to the head noun phrase of the relative clause should be made available in the experimental workspace. Evidence from recent studies of language acquisition has demonstrated the importance of satisfying the felicity conditions associated with the presuppositions of restrictive relative clauses and the detrimental effect that failure to meet these conditions has upon young children's comprehension. For example, Hamburger and Crain (1982) found significant improvement in preschool children's comprehension of relative clause sentences when felicity conditions were satisfied. They present evidence that improved performance derives from a reduction in processing demands associated with the planning required to make a response in an act-out task. It is possible that poor readers' difficulties with relative clause sentences might also be tied to excessive demands imposed by failure to meet felicity conditions.

Another finding from the literature on language acquisition suggests that

poor readers' impaired performance in the Mann et al. (1984) study may have been due, in part, to the number of relations among animate noun phrases that needed to be determined and acted out. In a study with pre-school children, Goodluck and Tavakolian (1982) demonstrated that performance on an act-out task similar to the one used in the Mann et al. study improved significantly when the number of animate noun phrases in relative clause sentences was reduced from three to two (e.g., by replacing a transitive verb in the relative clause with an intransitive verb). Improved performance in this case may also be explained in terms of a reduction in processing demands associated with the response plan needed to act out these sentences (Hamburger & Crain, 1984).

Finally, it was observed by Goldsmith (1980) that poor readers' comprehension of semantically constrained sentences surpassed that of unconstrained sentences. Semantically anomalous relations, which have often characterized sentences used in earlier studies (e.g., Byrne, 1981; Mann et al., 1984), may require additional processing in order to recover the intended relations among the constituents. Poor readers, with special weaknesses in verbal working memory, are presumably at a particular disadvantage under any circumstances that require reanalysis (Shankweiler et al., 1984).

Since only performance, not competence, is observed in tests of language ability, failure to control for factors that can unduly tax limited processing resources can mask expression of underlying linguistic knowledge. We suspect that previous studies of poor readers' comprehension of complex syntactic structures have often resulted in underestimates of their linguistic knowledge because, unwittingly, the experimental tasks posed extraneous demands on processing. When the goal of the research is to draw inferences about linguistic competence, experiments with the potential for disentangling deficits in structural knowledge from processing limitations are required. Bearing in mind the potential benefit of reducing processing demands for poor readers' comprehension of relative clauses, we incorporated four methodological changes to minimize processing load:

1. The restrictive function associated with restrictive relative clauses was satisfied.
2. Each of the test sentences indicated a single action relating two animate noun phrases.
3. In each test sentence, a third noun phrase was inanimate and conveyed descriptive information.
4. All test sentences indicated plausible events.

Together these steps were expected to minimize the demands associated with the comprehension task and permit the subjects to display their full level of linguistic competence.

This investigation was designed to permit a direct comparison of the findings with those of the Mann et al. (1984) study. By comparing performance in the two studies, we can begin to evaluate evidence for the two hypotheses under consideration. If the syntactic lag hypothesis is correct, we

would expect that poor readers should show no improvement when the task is made easier by minimizing processing demands because, in the absence of requisite structures, impaired performance should be observed even under the simplest conditions. On the other hand, if the processing limitation hypothesis is correct, we would expect poor readers' performance to improve as the task is simplified, reducing the disparity with good readers.

EXPERIMENT I: OBJECT MANIPULATION TEST

An object manipulation test was constructed in accordance with the methodological prescriptions described in the preceding paragraphs. This test incorporates the same structures studied in the research of Mann et al. (1984) and is intended as a sequel to that investigation.

Method

Subjects. The subjects were selected from four second-grade classes in a suburban public school system. All children for whom parental consent was obtained were given the Decoding Skills Test (DST) (Richardson & DiBenedetto, 1986) as a test of reading ability and the Peabody Picture Vocabulary Test - Revised (PPVT) (Dunn & Dunn, 1981). The PPVT was included to ensure that any obtained reader-group differences could not be attributed to limitations in word knowledge, which is an indicator of general verbal ability.

Nonoverlapping groups of good and poor readers were formed on the basis of three criteria: a combined word and nonword DST score less than 64 (poor readers) or greater than 83 (good readers),³ teacher confirmation of reading ability, and a PPVT score between 90 and 130. Grouping by these criteria yielded 18 children in the poor reader group (8 boys, 10 girls) and 16 children in the good reader group (6 boys, 10 girls). The groups did not differ significantly in age (range: 90-104 months), nor in PPVT scores (range: 90-126).⁴ Additionally, all subjects were native speakers of English and had no known speech or hearing deficiencies. The mean age, PPVT score, and DST score for each group are summarized in Table 1.

Materials. Four types of relative clause sentences were included in the test materials. An example of each is given below:

- (6) SS The lady who held an umbrella kissed the man.
- (7) SO The man who the lady kissed held an umbrella.
- (8) OS The lady kissed the man who held an umbrella.
- (9) OO The lady kissed the man who an umbrella covered.

Each sentence contains two animate noun phrases and one inanimate noun phrase and denotes plausible events among highly recognizable objects. The relations between animate noun phrases are reversible. In order to preserve the plausibility requirement, an action verb is used in the relative

Table 1. *Characteristics of the subjects*

	Good Readers (<i>N</i> =16)		Poor Readers (<i>N</i> =18)	
	Mean	<i>SD</i>	Mean	<i>SD</i>
Age (in months)	97.75	3.64	97.05	4.77
PPVT-Revised score	114.93	9.86	110.00	8.53
DST score ^a	98.37	8.63	47.77	15.53

^aMaximum DST score = 120

clause in OO-type sentences. For SO sentences, the inanimate noun phrase is placed in the main clause instead of in the relative clause to preserve plausibility and to allow for the possibility of a conjoined-clause misanalysis.⁵

Conjoined-clause sentences (CC), derived from the OS prototypes, were also included. It has been claimed that these structures are syntactically less complex than relative clause sentences and are mastered earlier in development. Each CC sentence contains an empty noun phrase in the second clause that is coreferential with the subject of the first clause. A sample CC is given in (10).

(10) CC The lady kissed the man and _ held an umbrella.

The test consisted of five sets of sentences in which the relations among nouns were varied in the five sentence types (SS, SO, OS, OO, CC). This yielded five sentences of each type, making a total of 25. These were randomized, and two test orders were prepared. Each test order was preceded by a short pretest, which consisted of three simple sentences and one complex sentence. The pretest and test sentences were recorded on audiotape at a natural conversational rate. Each sentence was preceded by an alerting bell. The pretest and test sentences are listed in Appendix 1.

Procedure. The subjects were tested individually in three sessions during the last quarter of the school year. The DST and PPVT were administered in the first session and one of the experimental tests was administered in each of the remaining sessions. Half of each reader group was tested on the object manipulation test in the second session and half received the sentence - picture matching test. This order was reversed in the third session, thus counterbalancing the presentation of the two tests.

At the onset of the object manipulation test, the subject was shown all of the toy objects to be used in the task and asked to name them. Any name that did not correspond to the name used in the test sentences was corrected. Before each test sentence was presented, objects corresponding to the nouns in the sentence were placed on the tabletop in front of the subject in a fixed, random order. As indicated earlier, two objects corresponding to the head noun in the relative clause were presented to meet the normal presupposi-

ions associated with the use of restrictive relative clauses. Although there are no such presuppositions associated with conjoined-clause sentences, an extra animate agent was placed in the work space to keep constant the number of items across sentence types. The subject listened to the test sentences using earphones at sound levels adjusted for comfortable listening.

The subject was instructed to listen to the entire sentence before proceeding to act out its meaning. Responses were coded by the experimenter to indicate the actions and relations enacted, as well as their order of occurrence. A sentence was repeated a second time if the subject requested it.

Results

Separate analyses were performed on the relative clause sentences and the conjoined-clause sentences in order to permit comparison with the results of the Mann et al. (1984) study. A response was considered correct if the relations indicated in both the main clause and the relative clause were properly enacted regardless of which clause was acted out first. Since there were no effects of test order, the remaining analyses were performed on the combined test orders.

Relative clause sentences. Both the good and poor readers acted out the relative clause sentences with a high level of success. The reader groups did not differ significantly in mean percentage of errors (good readers, 11.3%; poor readers, 18.1%). Table 2 displays the mean percentage of errors and standard deviations for each type of relative clause sentence for both reader groups.

The main effect of sentence types (SS, SO, OS, and OO relative clause sentences) was highly significant, $F(3, 96) = 17.94$, $p < .001$. There was, however, no significant interaction between reader group and sentence type, indicating that the good and poor readers were similarly affected by variations in sentence structure. Scheffe post hoc analyses ($p = .05$) indicated that SO sentences were more difficult than OO and SS sentences but were not more difficult than OS sentences. The SS sentences did not differ from OO sentences, but did differ from OS and SO sentences. Finally, OS and OO sentences did not differ from each other.

Analysis of errors. The distribution of errors was examined to determine whether errors previously identified in the literature as possibly signifying an immature stage of syntactic development occurred more often for the poor readers than for the good readers. Although the incidence of conjoined-clause errors differed significantly across sentence types, $F(2, 64) = 3.52$, $p = .03$ (with SO sentences producing the most errors of this type), there was no main effect of reader group and no Reader Group \times Sentence Type interaction. The good and poor readers did not differ in the number of conjoined-clause errors, and the pattern of errors across sentence type was similar for

Table 2. *Object manipulation test*^a

Relative Clause Structure	Good Readers		Poor Readers	
	Mean	SD	Mean	SD
SS	2.6	6.8	3.4	7.6
SO	25.0	28.8	35.6	26.2
OS	11.2	14.6	20.0	22.8
OO	6.2	12.0	13.2	21.8

^aMean percentage of errors and standard deviations for relative clause sentences.

both reader groups. Also, other error types noted in previous investigations, for example, minimum distance errors⁶ that were noted in the Mann et al. (1984) study, failed to distinguish between reader groups in the present study.

There was no difference between reader groups in the order in which the information in the two clauses was acted out. In general, both reader groups acted out the descriptive information first. For example, in the SO sentence (7) "The man who the lady kissed *held an umbrella*," both the good and poor readers put the umbrella in the man's hand before they had the lady kiss him.⁷

Conjoined-clause sentences. The good readers made significantly fewer errors (2.6%) than the poor readers (17.8%) in the conjoined-clause sentences ($t(32)=2.71, p=.01$). Despite the poor readers' greater percentage of errors in this sentence type, the order in which they acted out the clauses did not differ significantly from that of the good readers. Enactments in which the second-mentioned clause was acted out first occurred 67.6% and 78.8% of the time for the good and poor readers, respectively.

Discussion

As noted in the Introduction, an examination of both error rates and pattern of errors by good and poor readers is critical for evaluating the two hypothesized sources of poor readers' difficulties in comprehension. We are justified in concluding that the syntactic lag hypothesis is correct only if the poor readers' percentage of errors, types of errors, and items on which they err are discrepant from those of good readers. The processing limitation hypothesis is correct only if the following criteria are met:

1. Both reader groups are similarly affected by syntactic complexity - that is, those relative clause sentences that are most difficult for poor readers are similarly the most difficult for good readers.

2. The types of errors made by poor readers are not qualitatively different from those made by good readers.
3. There is improved performance on tests in which processing demands have been reduced as compared to tests in which they were not reduced.
4. The performance of poor readers is well above chance on some examples of the structure being investigated.

The findings of this experiment clearly support the processing limitation hypothesis. The following facts are indicative. First, there was no difference in the incidence of errors between the reader groups on relative clause sentences. Second, both reader groups were similarly affected by syntactic variation as demonstrated by the lack of a Reader Group \times Sentence Type interaction. Finally, the types of errors that the poor readers made were similar to those made by the good readers, and no error type was made more often by the poor readers. These findings are inconsistent with the syntactic lag hypothesis. Instead, they suggest that the processing limitation hypothesis may provide a better account of poor readers' inferior performance in earlier studies.

The effects of the steps we adopted to ease processing demands can be evaluated by comparing the good and poor readers' performance in this study with the reader groups' performance in the Mann et al. (1984) study in which animacy, plausibility, and felicity conditions were not controlled. Figure 1 presents a comparison of the percentage of errors for the good and poor readers on the object manipulation test in the two studies. Both reader groups in the present study performed at a significantly higher level than those in the Mann et al. study (even though the subjects in the present study were a year younger). The good readers made 11.3% errors compared with 25.7% in the Mann et al. study ($t(32)=2.81, p < .01$), and the poor readers made 18.1% errors compared with 40.8% in the earlier study ($t(33)=4.01, p < .001$). However, it should be noted that the same pattern of errors across sentence types was found in both studies. Also, in contrast to the Mann et al. (1984) study, there were no differences between reader groups in this study for any of the prevalent error types. In sum, the reduction in percentage of errors that occurred in the present study strongly suggests that poor readers' impaired performance in earlier studies is attributable to processing factors and not to a delay in the acquisition of syntactic knowledge.

A further aspect of the poor readers' performance on the object manipulation test supports this conclusion. This concerns the unexpectedly high incidence of errors on the conjoined-clause sentences. The difficulty, we suspect, may have been due to the unusual construction of these sentences. As explained earlier, these sentences were derived from the OS relative clause sentences in order to investigate the possibility that some subjects were adopting the conjoined-clause analysis posited by Tavakolian (1981). In the test sentences, the descriptive information specified in the OS relative clause appears after the overt action is specified, as in (11), creating a conflict between the conceptual order of the information and its order of mention.

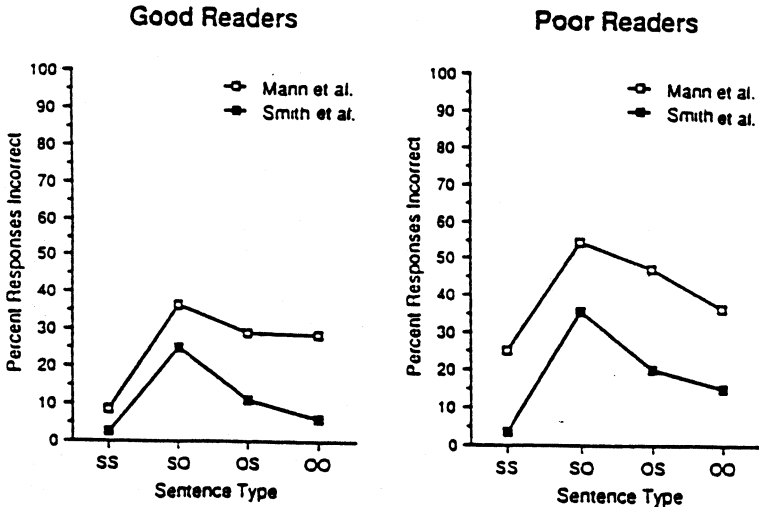


Figure 1. Comparison of the percentage of errors for the good and poor readers on the object manipulation test in this study and in the Mann et al. (1984) study.

- (11) CC The lady kissed the man and held an umbrella.

Intuitively, one might suppose that in normal conversation the information in this sentence would have been conveyed in the following manner:

- (12) The lady held an umbrella and kissed the man.

This intuition is supported by the finding that the second clause was enacted first in 72.3% of all responses. The subjects appear to have treated the information in the second clause as if it were descriptive information representing some prior condition, even though conjoined-clause sentences do not have the inherent ordering of clauses characteristic of sentences with restrictive relative clauses. Given that these conjoined-clause sentences conveyed information in a way that may have unintentionally violated conversational conventions, they may have imposed a heavy processing load. Consequently, the poor readers were adversely affected.⁸ This finding underscores our contention that poor readers' performance on tests of comprehension is closely tied to aspects of processing and not necessarily to aspects of syntactic complexity.

In summary, the main finding was that the poor readers' performance on the relative clause sentences in the object manipulation test did not differ from the good readers' performance either in percentage of errors or in pattern of responses. Also, the incidence of errors was significantly reduced in comparison with the Mann et al. (1984) study, even though the subjects were a year younger. Taken together, these findings support the processing limitation hypothesis over the syntactic lag hypothesis.

EXPERIMENT II: SENTENCE-PICTURE MATCHING TEST

The second experiment was designed to test further for the possibility that certain sentences containing relative clauses are misconstrued by poor readers as sentences containing conjoined clauses. This type of error in comprehension occurred relatively frequently in some previous research on interpretations of relative clause sentences by reading-disabled children (Mann et al., 1984; Stein et al., 1984). It was reasoned that if the syntactic lag hypothesis is correct, we would expect poor readers to be more susceptible to a conjoined-clause interpretation than good readers. The processing limitation hypothesis, on the other hand, would expect no qualitative differences between reader groups.

A sensitive test of a tendency to construe sentences containing a relative clause as though they contain conjoined clauses can be made by forcing a choice between two pictures, one of which depicts the conjoined-clause analysis. (This technique was used successfully in examining comprehension of relative clauses by much younger children; see Crain & Fodor, forthcoming.) Accordingly, a two-choice sentence-picture matching test was constructed by modifying the sentence material in Experiment I and providing appropriate pictures. For each SO, OS, and OO relative clause sentence, one picture foil depicted the incorrect conjoined-clause analysis interpretation. Since a conjoined-clause analysis interpretation is equivalent to the correct interpretation of an SS relative clause sentence, comprehension of this sentence type was examined by contrasting the correct interpretation with a foil that depicted the interpretation of the information in the main clause only.

Method

Materials. A: Test Sentences. The five types of stimulus sentences used in Experiment I were modified in this experiment by changing the verb tense from past to present progressive to accommodate the use of a two-choice sentence-picture matching test. A sample set of test sentences is listed below:

- (13) SS The lady who is holding an umbrella is kissing the man.
- (14) SO The man who the lady is kissing is holding an umbrella.
- (15) OS The lady is kissing the man who is holding an umbrella.
- (16) OO The lady is kissing the man who an umbrella is covering.
- (17) CC The lady is kissing the man and is holding an umbrella.

Additional sentences, with different nouns and verbs, were added as controls to ascertain that the subjects were attending to the entire sentence. These control sentences were of the same form as three of the experimental sentences (SS, OS, CC), but their respective foils differed. The picture foils for all sentence types are described later.

B: Test Design. The test contained 40 sentences: the five (modified) sets of sentences (SS, SO, OS, OO, CC) from the object manipulation test plus five

an extra object, which did not satisfy the felicity condition of the relative clause but was appropriate for the sentence context, was included in the background to maintain the same number of objects in each picture.

Each picture measured 4×6 inches, and was displayed on an $8\frac{1}{2} \times 11$ inch sheet with a one-inch border on the top, bottom and right side, and a $1\frac{1}{2}$ inch border on the left side to accommodate binding. In half of the arrays, the correct picture was placed at the bottom. A sample OS picture array is displayed in Appendix 3.

Procedure. Administration of the sentence-picture matching test was counterbalanced with the object manipulation test (see Experiment I, Method). The subjects, each of whom also participated in Experiment I, were tested individually. For each trial, the picture array was presented immediately before the onset of the tape-recorded sentence. The subjects were instructed to listen carefully to the entire sentence, to look carefully at both pictures in the array, and then to point to the picture that showed the meaning of the sentence. Headphones were used with the sound level adjusted for each subject's comfort. A sentence was repeated a second time if the subject requested it.

Results

Separate analyses were performed on the relative clause sentences, the conjoined-clause sentences, and the control sentences. Since there was no effect of test order, the remaining analyses were performed on the combined test orders.

Table 3 displays the mean percentage of errors and standard deviations for each type of relative clause sentence for both reader groups. The good readers averaged 11.3% errors and the poor readers 18.6% errors, $F(1, 32) = 4.69$, $p = .04$. Although the poor readers chose the erroneous conjoined-clause interpretation of relative clause sentences slightly (but significantly) more often than the good readers, both reader groups achieved a high overall level of success. In fact, the difference between the mean percentage of errors for the two groups on this test was very similar to the difference obtained with the object manipulation test. Further, as was the case with the object manipulation test, there was a highly significant effect of sentence type, $F(3, 96) = 21.89$, $p < .001$, but no reader Group \times Sentence Type interaction. Post hoc Scheffe analyses ($p = .05$) indicated that SO sentences were more difficult than all other sentence types. The OO and OS sentence types were not different from each other, but both were more difficult than SS sentences.

There was no significant difference between reader groups in the percentage of errors on conjoined-clause sentences (good readers, 7.6%; poor readers, 3.4%). Only a single error occurred in the control sentences.

Table 3. *Sentence-picture matching test*^a

Relative Clause Structure	Good Readers		Poor Readers	
	Mean	SD	Mean	SD
SS	0.0	—	1.2	4.8
SO	22.6	17.4	38.8	31.8
OS	5.0	11.4	14.4	17.8
OO	12.6	17.8	20.0	19.4

^aMean percentage of errors and standard deviations for relative clause sentences.

Discussion

In the sentence-picture matching test, there was a small but significant difference between the reader groups in the mean percentage of errors (i.e., incorrect conjoined-clause interpretations) for the relative clause sentences. However, no subjects consistently chose this interpretation across all sentence types. Further, the difference between the mean percentages of errors for the two groups in the sentence-picture matching test was very similar to the difference found in the object manipulation test, and both reader groups were similarly affected by variations in syntactic structure introduced by the different types of relative clause sentences. The fact that the poor readers gave a high percentage of correct responses in the sentence-picture matching test (and in the object manipulation test), together with the fact that they showed a similar pattern of errors across sentence types as the good readers in both tasks, suggests that the difficulties poor readers have shown with relative clause sentences in past studies cannot be attributed to a syntactic lag.

In contrast with the results from the object manipulation test – in which the reader groups differed only on conjoined-clause sentences – in the sentence-picture matching test, conjoined-clause sentences yielded no reader group difference. We can only speculate about the reasons for this disparity. Certainly, the fact that the poor readers did not differ from the good readers in the percentage of errors in conjoined-clause sentences in this experiment is in keeping with the lower overall processing demands imposed by a forced-choice selection procedure (see Shankweiler et al., 1984). In this case, the subjects merely had to affirm or deny the accuracy of what was depicted, rather than plan and execute a set of actions demonstrating comprehension of this information. This interpretation gains cogency in light of the analysis by Hamburger and Crain (1984), who have explicitly characterized the processing demands associated with the planning step in act-out tasks. They demonstrated, moreover, that by minimizing the processing demands associated with the planning step, young children's performance is enhanced. The finding that the poor readers were not impaired in comprehension of conjoined-clause sentences when the processing load associated with these

sentences was minimized, is, of course, consistent with the processing limitation hypothesis. This finding cannot easily be assimilated by the syntactic lag hypothesis.

GENERAL DISCUSSION

The aim of this research was to pinpoint the source of poor readers' comprehension failures in spoken sentences containing complex syntactic structures. Sentences with relative clauses provided a vehicle for testing between two hypotheses either of which could, in principle, explain the comprehension difficulties uncovered in previous research. As we saw, the syntactic lag hypothesis views poor readers as delayed in the acquisition of complex syntactic structures. Deficits in comprehension thus reflect a lack of full linguistic competence on the part of poor readers. On this account, poor readers are expected to encounter difficulty with putatively late-developing complex syntactic structures such as relative clauses. Their errors, too, should reflect their relatively immature grammars. For instance, poor readers might be expected to make more conjoined-clause analysis errors than good readers if adultlike recursive rules have yet to become a part of their grammatical knowledge. Further, since the requisite structures are hypothesized not to be in place, poor readers should be expected to make more errors than good readers in spite of steps one might take to reduce processing demands.

By contrast, the processing limitation hypothesis maintains that even the most complex structures are in place at the onset of reading instruction. Errors in comprehension on the part of poor readers are not the result of gaps in linguistic competence but, instead, are taken to reflect performance failures deriving from deficiencies in verbal working memory due to limitations in phonological processing. The processing limitation hypothesis, but not the syntactic lag hypothesis, anticipated that poor readers would achieve a high level of performance on the tasks employed in the present study, which reduce the burdens on verbal working memory. Further, the processing limitation hypothesis anticipated a substantial reduction in errors in the present study as compared to previous studies in which steps were not taken to hold processing demands to a minimum. Finally, this hypothesis predicted that poor readers' overall performance should parallel that of good readers.

In keeping with these predictions, the poor readers in the present study performed at a high level of success on both experimental tasks. On the object manipulation test, they were not differentiated from the good readers either with respect to percentage of errors or types of errors. Further, there was a significant reduction in the percentage of errors as compared to the object manipulation test of Mann et al. (1984), a difference that must reflect the effectiveness of our attempt to simplify the task. Finally, the poor readers responded in the same conceptual manner as the good readers. On the sentence-picture matching test, there was a marginally significant reader-group difference. However, the poor readers' performance did not deviate

from the good readers' performance on any of the measures that could be taken to indicate delayed acquisition of syntactic knowledge of relative clauses - for example, different types of errors or a different rank order of difficulty across types of relative clause sentences. Taken together, these findings support the expectation of the processing limitation hypothesis that both reader groups are indistinguishable in syntactic competence, and that any differences in comprehension in children differing in reading ability must be attributable to other causes. We should not lose sight of the fact that the subjects in the present study were a year younger than those tested in the Mann et al. study. This adds to the weight of the evidence in favor of the processing limitation hypothesis. Under the syntactic lag hypothesis, younger poor readers would more likely show evidence of delayed acquisition of complex syntactic structures. But since the younger children in the present study were able to comprehend sentences containing complex relative clause constructions when processing demands were held to a minimum, the syntactic lag hypothesis is rendered less plausible as an explanation of poor readers' comprehension difficulties.

Earlier, we noted that findings over a range of measures indicate that poor readers are deficient in phonological processing. It has been hypothesized that one consequence of such a deficit is failure to apprehend the phonological structure of words, making it inordinately difficult for the child to discover how the spelling of the word is related to its phonological structure. Thus, in this hypothesis, the development of efficient word recognition strategies is hampered because the affected individual has not learned to decode. As indicated earlier, there exists considerable empirical support for this claim. But decoding difficulties are not the only consequence of a deficit in phonological processing: a phonological deficit may also impose severe limitations on the operation of verbal working memory. Sentence comprehension may be affected adversely both in reading and in the apprehension of spoken language.

Let us now spell out how a phonological processing deficit may result in failures in sentence comprehension through its impact on verbal working memory. In this account, which is presented in greater detail elsewhere (see Crain et al., in press; Shankweiler & Crain, 1986), the well attested deficiencies of poor readers on tasks of ordered recall lead to the expectation that higher-level processes such as syntactic comprehension would be compromised by poor readers' failures to adequately retain phonological information during sentence processing. In effect, there is a bottleneck that constricts the flow of information from lower levels to higher levels (see Perfetti, 1985, for a related account). This follows from a very general assumption concerning the architecture of the language apparatus. To explain how a deficit at one level can give rise to dysfunction at other levels, we have appealed to the proposition that the language apparatus consists of hierarchically organized subcomponents with information flowing unidirectionally from lower to higher levels of the system.⁹ A role for verbal working memory is posited to support processing within each structural component of language and to effect the orderly transfer of information between com-

ponents. (Other accounts which emphasize the control functions of working memory in addition to its short-term storage functions have been advanced by Baddeley & Hitch, 1974, and Daneman & Carpenter, 1980.)

This conception of poor readers' difficulties in processing spoken sentences applies with even greater force to reading, because reading imposes an additional step upon the language understanding system - a phonological interpretation must be assigned to an orthographic representation by a decoding step. Whereas in spoken language word recognition is carried out quite automatically by machinery that evolution has crafted for this purpose, reading depends on orthographic skills that are not part of the biological endowment for language (see Liberman, 1988, for discussion). When orthographic decoding skills are poorly established, as in the case of a beginning reader or a person with a persistent reading disability, syntactic and semantic processing is severely hampered because the limited verbal working memory resources are used up in attempts to identify the words of the text. Thus, until word recognition skills are well established, reading may be expected to impose greater demands on processing capacities than speech (Shankweiler & Crain, 1986). Here, as in the case of spoken sentence comprehension, failures to understand complex structures may be attributable to limitations in phonological processing and not to a delay in the acquisition of syntactic structures. Therefore, in reading comprehension, as in spoken language comprehension, we should observe improved performance in higher-level processes when demands associated with lower-level components of the task are reduced.

APPENDIX 1

STIMULUS SENTENCES FOR OBJECT MANIPULATION TEST

- SS The lady who held an umbrella kissed the man.
 - SO The man who the lady kissed held an umbrella.
 - OS The lady kissed the man who held an umbrella.
 - OO The lady kissed the man who an umbrella covered.
 - CC The lady kissed the man and held an umbrella.
-
- SS The lady who carried a suitcase touched the man.
 - SO The lady who the man touched carried a suitcase.
 - OS The man touched the lady who carried a suitcase.
 - OO The man touched the lady who a scarf was on.
 - CC The man touched the lady and carried a suitcase.
-
- SS The boy who carried a banana chased the monkey.
 - SO The boy who the monkey chased carried a banana.
 - OS The monkey chased the boy who carried a banana.
 - OO The monkey chased the boy who a hat was on.
 - CC The monkey chased the boy and carried a banana.

- SS The girl who hugged a teddy bear pushed the boy.
- SO The boy who the girl pushed hugged a teddy bear.
- OS The girl pushed the boy who hugged a teddy bear.
- OO The boy pushed the girl who the ice cream fell on.
- CC The boy pushed the girl and hugged a teddy bear.

- SS The giraffe that ate the hay followed the elephant.
- SO The giraffe that the elephant followed ate the hay.
- OS The elephant followed the giraffe that ate the hay.
- OO The elephant followed the giraffe that a rope hung from.
- CC The giraffe followed the elephant and ate the hay.

PRETEST

- The girl pushed the boy.
- The man touched the lady.
- The monkey followed the giraffe.
- The boy held a teddy bear and the girl carried a ball.

APPENDIX 2

STIMULUS SENTENCES FOR SENTENCE-PICTURE MATCHING TEST

- SS The lady who is holding an umbrella is kissing the man.
 - SO The man who the lady is kissing is holding an umbrella.
 - OS The lady is kissing the man who is holding an umbrella.
 - OO The lady is kissing the man who an umbrella is covering.
 - CC The lady is kissing the man and is holding an umbrella.
-
- SS The lady who is carrying a suitcase touched the man.
 - SO The lady who the man is touching is carrying a suitcase.
 - OS The man is touching the lady who is carrying a suitcase.
 - OO The man is touching the lady who a scarf is on.
 - CC The man is touching the lady and is carrying a suitcase.
-
- SS The boy who is carrying a banana is chasing the monkey.
 - SO The boy who the monkey is chasing is carrying a banana.
 - OS The monkey is chasing the boy who is carrying a banana.
 - OO The monkey is chasing the boy who a hat is on.
 - CC The monkey is chasing the boy and is carrying a banana.
-
- SS The girl who is hugging a teddy bear is pushing the boy.
 - SO The boy who the girl is pushing is hugging a teddy bear.
 - OS The girl is pushing the boy who is hugging a teddy bear.
 - OO The boy is pushing the girl who the ice cream is falling on.
 - CC The boy is pushing the girl and is hugging a teddy bear.

- SS The giraffe that is eating the hay is following the elephant.
- SO The giraffe that the elephant is following is eating the hay.
- OS The elephant is following the giraffe that is eating the hay.
- OO The elephant is following the giraffe that a rope is hanging from.
- CC The giraffe is following the elephant and is eating the hay.

CONTROL SENTENCES

- SS The lady who is wearing a hat is hugging the baby.
- OS The lady is hugging the baby who is wearing a hat.
- CC The lady is hugging the baby and is wearing a hat.

- SS The clown who is holding the flowers is hitting the girl.
- OS The girl is hitting the clown who is holding the flowers.
- CC The clown is hitting the girl and is holding the flowers.

- SS The girl who is holding a ball is kicking the boy.
- OS The boy is kicking the girl who is holding a ball.
- CC The boy is kicking the girl and is holding a ball.

- SS The boy who is eating the ice cream is pulling the girl.
- OS The boy is pulling the girl who is eating the ice cream.
- CC The girl is pulling the boy and is eating the ice cream.

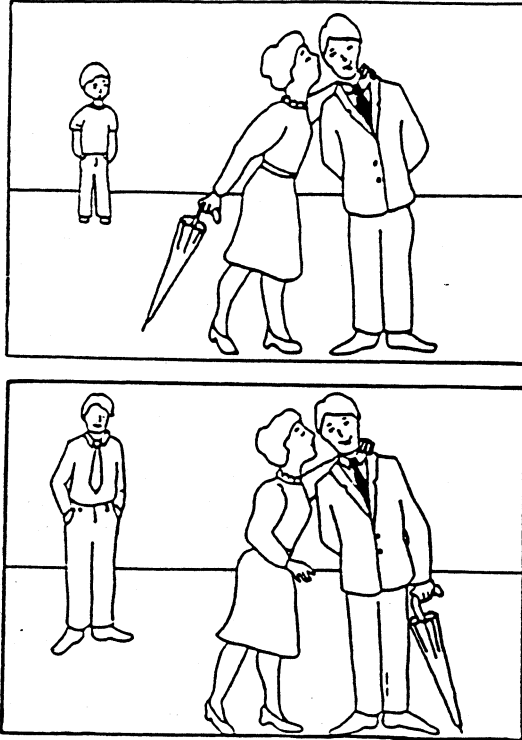
- SS The cat that is wearing a bow is licking the rabbit.
- OS The rabbit is licking the cat that is wearing a bow.
- OO The cat is licking the rabbit and is wearing a bow.

PRETEST

- The girl is pushing the boy.
- The man is touching the lady.
- The monkey is following the giraffe.
- The boy is holding a teddy bear and the girl is carrying a ball.

APPENDIX 3

SAMPLE PICTURE ARRAY FOR SENTENCE-PICTURE
MATCHING TEST



OS The lady is kissing the man who is holding an umbrella.

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NOTES

1. The evidence that poor readers share in common difficulties in decoding words in print is overwhelming (see Chall, 1967; Perfetti, 1985; Stanovich, 1986). Evidence that the decoding problems are a reflection of wider deficiencies in processing the phonological components of language is summarized in several places (Liberman & Shankweiler, 1985; Rozin & Gleitman, 1977; Shankweiler & Liberman, 1972). Verbal working memory is another aspect of phonological processing that is deficient in poor readers (see Jorm, 1983; Liberman & Shankweiler, 1985; Wagner & Torgesen, 1987).
2. It should be noted that the difficulties poor readers encounter in sentence comprehension would often be missed in everyday settings, but may come to light in tasks that present complex structures without the contextual support that is found in ordinary spoken discourse.
3. In this study, a subject's score for each DST subtest consisted of the number of items read correctly prior to making ten errors in a row or completing the 60 item list. The maximum combined score was 120.
4. Considerations governing the selection of an appropriate control group in investigations of the causes of reading disability are discussed in Shankweiler, Crain, Brady, and Macaruso (in press).
5. Erroneous conjoined-clause interpretations of each type of relative clause sentence are described in Tavakolian (1981). For example, in SO sentence (7), a conjoined-clause misanalysis yields two possible interpretations: either the man kissed the lady and held an umbrella, or the lady kissed the man and held an umbrella. Tavakolian supposed that her preschool subjects may have applied preexisting phrase structure rules for conjoined clause sentences to relative clause sentences.
6. Minimum distance errors are based on the minimum-distance principle, which holds that a noun most proximal to the verb is interpreted as its missing subject (Rosenbaum, 1967; Chomsky, 1969).
7. For the SO sentences, in which the descriptive information is contained in the main clause, subjects in the present study acted out the main clause first 80.6% of the time (good readers: 74.7%; poor readers: 86.4%). This contrasts with the findings of a follow-up study by Crain, Shankweiler, Macaruso, and Bar-Shalom (in press) in which the test sentences contained no descriptive information. In that study both the good and poor readers acted out the relative clause first 100% of the time for the SO sentences. Since, in the present study, the descriptive information appears in the relative clause for the SS, OS, and OO sentences, the two response tendencies cannot be separated for these sentence types.
8. It is important to note that the poor readers did not have more difficulty than the good readers with OS sentences, although in these sentences, too, the descriptive information followed mention of the overt action, as in the conjoined-clause sentences. The absence of reader-group differences on OS sentences can be understood in light of the difference in pragmatic function of the two sentence types. Conceptually, the second conjunct of a conjoined-clause sentence is generally the (temporally) second event in an action sequence. In contrast, the relative clause, which appears second in an OS relative, has been found to denote the conceptually prior event in sentences which contain two action sequences (see Hamburger & Crain, 1982, for discussion).

9. This explanation is developed within a framework that has long guided research on speech and reading at Haskins Laboratories (see Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Related views of the language processing system have been advanced by Forster (1979) and Fodor (1983).

REFERENCES

- Baddeley, A. D., & Hitch, G. B. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and activation* (Vol. 4). New York: Academic.
- Bohannon, J. N., Warren-Leubecker, A., & Hepler, N. (1984). Word order awareness and early reading. *Child Development*, 55, 1541-1548.
- Bowey, J. A. (1986). Syntactic awareness in verbal performance from preschool to fifth grade. *Journal of Psycholinguistic Research*, 15, 285-308.
- Byrne, B. (1981). Deficient syntactic control in poor readers: Is a weak phonetic memory code responsible? *Applied Psycholinguistics*, 2, 201-212.
- Chall, J. (1967). *Learning to read: The great debate*. New York: McGraw-Hill.
- Chomsky, C. (1969). *The acquisition of syntax in children from 5 to 10*. Cambridge, MA: MIT Press.
- Conrad, R. (1964). Acoustic confusions in immediate memory. *British Journal of Psychology*, 3, 75-84.
- (1972). Speech and reading. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading*. Cambridge, MA: MIT Press.
- Conrad, R., & Hull, A. J. (1964). Information, acoustic confusions, and memory span. *British Journal of Psychology*, 55, 75-84.
- Crain, S., & Fodor, J. D. (forthcoming). Competence and performance in child language. In E. Dromi (Ed.), *Language and cognition: A developmental perspective*. Norwood, NJ: Ablex.
- Crain, S., & Shankweiler, D. (1988). Syntactic complexity and reading acquisition. In A. Davison & G. Green (Eds.), *Linguistic complexity and text comprehension: Readability issues reconsidered*. Hillsdale, NJ: Erlbaum.
- Crain, S., Shankweiler, D., Macaruso, P., & Bar-Shalom, E. (in press). Working memory and sentence comprehension: Investigations of children with reading disorder. In G. Vallar & T. Shallice (Eds.), *Impairments of short-term memory*. Cambridge: Cambridge University Press.
- Crowder, R. G. (1978). Audition and speech coding in short-term memory. In J. Requin (Ed.), *Attention and performance, VII*. Hillsdale, NJ: Erlbaum.
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, 19, 450-466.
- de Hirsch, K., Jansky, J., & Langford, W. (1966). *Predicting reading failure*. New York: Harper & Row.
- Dunn, L., & Dunn, L. (1981). *Peabody Picture Vocabulary Test-Revised*. Circle Pines, MN: American Guidance Service.
- Fletcher, J. J., Satz, P., & Scholes, R. (1981). Developmental changes in the linguistic performance correlates of reading achievement. *Brain and Language*, 13, 78-90.
- Fodor, J. A. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- Forrest-Pressley, D. L., & Waller, T. G. (1984). *Cognition, metacognition and reading*. New York: Springer Verlag.
- Forster, K. (1979). Levels of processing and the structure of the language processor. In W. E. Cooper & E. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*. Hillsdale, NJ: Erlbaum.
- Fowler, A. (1988). Grammaticality judgments and reading skill in grade 2. *Annals of Dyslexia*, 38, 73-94.
- Fry, M. A., Johnson, C. S., & Muehl, S. (1970). Oral language production in relation to reading achievement among select second graders. In D. J. Bakker & P. Satz (Eds.), *Specific reading disabilities: Advances in theory and method*. Rotterdam: Rotterdam University Press.

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- Goldsmith, S. (1980). *Psycholinguistic bases of reading disability: A study in sentence comprehension*. Unpublished doctoral dissertation, The City University of New York.
- Goodluck, H., & Tavakolian, S. (1982). Competence and processing in children's grammar of relative clauses. *Cognition*, 11, 1-27.
- Hamburger, H., & Crain, S. (1982). Relative acquisition. In S. Kuczaj II (Ed.), *Language development: Vol. 1. Syntax and semantics*. Hillsdale, NJ: Erlbaum.
- (1984). Acquisition of cognitive compiling. *Cognition*, 17, 85-136.
- Jorm, A. (1983). Specific reading retardation and working memory: A review. *British Journal of Psychology*, 74, 311-342.
- Liberman, A. M. (1989). *Reading is hard just because listening is easy*. In C. von Euler (Ed.), *Wenner-Gren International Symposium Series: Brain and reading*. Hampshire, England: Macmillan.
- Liberman, A. M., Cooper, F. S., Shankweiler, D., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review*, 74, 431-461.
- Liberman, I. Y. (1983). A language-oriented view of reading and its disabilities. In H. J. Myklebust (Ed.), *Progress in learning disabilities* (Vol. 5). New York: Grune & Stratton.
- Liberman, I. Y., Mann, V. A., Shankweiler, D., & Werfelman, M. (1982). Children's memory for recurring linguistic and nonlinguistic material in relation to reading ability. *Cortex*, 18, 367-375.
- Liberman, I. Y., & Shankweiler, D. (1985). Phonology and the problems of learning to read and write. *Remedial and Special Education*, 6, 3-17.
- Mann, V. A., Liberman, I. Y., & Shankweiler, D. (1980). Children's memory for sentences and word strings in relation to reading ability. *Memory and Cognition*, 8, 329-335.
- Mann, V. A., Shankweiler, D., & Smith, S. T. (1984). The association between comprehension of spoken sentences and early reading ability: The role of phonetic representation. *Journal of Child Language*, 11, 627-643.
- Mattis, S., French, J. H., & Rapin, I. (1975). Dyslexia in children and young adults: Three independent neuropsychological syndromes. *Developmental Medicine and Child Neurology*, 17, 150-163.
- Menyuk, P., & Flood, J. (1981). Language development, reading/writing problems and remediation. *Bulletin of the Orton Society*, 31, 13-28.
- Morice, R., & Slaghuys, W. (1985). Language performance and reading ability at 8 years of age. *Applied Psycholinguistics*, 6, 141-160.
- Nelson, H. E., & Warrington, E. K. (1980). An investigation of memory function in dyslexic children. *British Journal of Psychology*, 71, 487-503.
- Perfetti, C. A. (1985). *Reading ability*. New York: Oxford University Press.
- Richardson, E., & DiBenedetto, B. (1986). *Decoding skills test*. Parkton, MD: York Press.
- Roit, M. L. (1980). *Syntactic development in normals and dyslexics: An empirical examination of two theoretical explanations of dyslexia*. Unpublished doctoral dissertation, Harvard University.
- Rosenbaum, P. S. (1967). *The grammar of english predicate construction*. Cambridge, MA: MIT Press.
- Rozin, P., & Gleitman, L. R. (1977). The structure and acquisition of reading II: The reading process and the acquisition of the alphabet principle. In A. S. Reber & D. L. Scarborough (Eds.), *Toward a psychology of reading*. Hillsdale, NJ: Erlbaum.
- Shankweiler, D., & Crain, S. (1986). Language mechanisms and reading disorders: A modular approach. *Cognition*, 24, 139-168.
- Shankweiler, D., Crain, S., Brady, S., & Macaruso, P. (in press). Identifying the causes of reading disability. In P. B. Gough (Ed.), *Reading acquisition*. Hillsdale, NJ: Erlbaum.
- Shankweiler, D., & Liberman, I. Y. (1972). Misreading: A search for causes. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading*. Cambridge, MA: MIT Press.
- Shankweiler, D., Smith, S. T., & Mann, V. A. (1984). Repetition and comprehension of spoken sentences by reading-disabled children. *Brain and Language*, 23, 241-257.
- Sheldon, A. (1974). The role of parallel function in the acquisition of relative clauses in English. *Journal of Verbal Learning and Verbal Behavior*, 13, 272-281.

- Smith, S. T., Mann, V. A., & Shankweiler, D. (1986). Spoken sentence comprehension by good and poor readers: A study with the Token Test. *Cortex*, 22, 627-632.
- Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, 21, 360-406.
- Stein, C. L., Cairns, H. S., & Zurif, E. B. (1984). Sentence comprehension limitations related to syntactic deficits in reading-disabled children. *Applied Psycholinguistics*, 5, 305-322.
- Tavakolian, S. L. (1981). The conjoined-clause analysis of relative clauses. In S. L. Tavakolian (Ed.), *Language acquisition and linguistic theory*. Cambridge, MA: MIT Press.
- Vellutino, F. R. (1979). *Dyslexia: Theory and research*. Cambridge, MA: MIT Press.
- Vellutino, F. R., Pruzek, R. M., Steger, J. A., & Meshoulam, U. (1973). Immediate visual recall in poor and normal readers as a function of orthographic-linguistic familiarity. *Cortex*, 9, 370-386.
- Vogel, S. A. (1975). *Syntactic abilities in normal and dyslexic children*. Baltimore: University Park Press.
- Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101, 192-212.
- Weinstein, R., & Rabinovitch, M. S. (1971). Sentence structure and retention in good and poor readers. *Journal of Educational Psychology*, 62, 25-30.
- Wiig, E. H., & Roach, M. A. (1975). Immediate recall of semantically varied sentences by learning disabled readers. *Perceptual Motor Skills*, 40, 119-125.