PHONOLOGY AND READING DISABILITY
Solving the Reading Puzzle

Edited by
Donald Shankweiler, Ph.D.
Fellow, International Academy for Research in Learning Disabilities
Research Associate, Haskins Laboratories
Professor, University of Connecticut

and

Isabelle Y. Liberman, Ph.D.
Fellow, International Academy for Research in Learning Disabilities
Research Associate, Haskins Laboratories
Professor Emerita, University of Connecticut

International Academy for Research in Learning Disabilities Monograph Series, Number 6

Ann Arbor **The University of Michigan Press**

1989

CHAPTER 2

How Problems of Comprehension Are Related to Difficulties in Decoding

Donald Shankweiler

Abstract

Those who view reading difficulties from the standpoint of comprehension have often focused on a different set of problems than those whose standpoint is the identification of individual words. Nonetheless the two kinds of problems—word decoding and sentence understanding—may be connected in several ways, as Perfetti and his colleagues have appreciated. The question considered in this chapter is whether the major difficulties at the level of the word and at the level of the sentence (and larger units of text) could have a common source. The chapter proposes how difficulties at each level might stem from a deficit in phonological processing, and it counters some empirical challenges to this viewpoint with arguments based on recent research.

Résumé

Ceux qui étudient les problèmes de lecture au niveau de la compréhension et ceux qui les étudient au niveau de l'identification des mots individuels, ils ont souvent concentré sur un groupe de problèmes très différents. Néanmoins, les deux types de problèmes—le déchiffrement des mots et la compréhension des phrases—dont Perfetti et d'autres se sont rendus compte, peuvent être liés en plusieurs façons. La question adressée dans cet article, cèst s'il y a une source en commun

entre les difficultés au niveau du mot et celles au niveau de la phrase (et des segments plus larges du texte). L'article propose que les difficultés à chaque niveau peuvent être causées par un déficit dans les procès phonologiques et il contrarie quelques défis empiriques à ce point du vue à l'aide d'arguments basés sur de nouvelles recherches.

Zusammenfassung

Wissenschaftler, die Leseschwierigkeiten vom Blickwinkel des Verstehens aus betrachten, beschäftigen sich oft mit anderen Problemen, als jene, die sich auf die Erkennung einzelner Worte konzentrieren. Diese beiden Probleme—Worterkennung und Verstehen ganzer Sätze—sind aber wahrscheinlich miteinander verbunden, wie Perfetti und seine Mitarbeiter gezeigt haben. Der vorliegende Artikel behandelt die Frage, ob die hauptsächlichen Schwierigkeiten auf dem Niveau des Wortes und des Satzes (oder längerer Texteinheiten) einen gemeinsamen Ursprung haben. Wir schlagen vor, dass Leseschwierigkeiten in beiden Fällen auf mangelhafte phonologische Verarbeitung zuruckzuführen sind. Empirische Daten, die gegen ein solches Konzept angeführt wurden, scheinen in Anbetracht von Ergebnissen aus unseren letzten Untersuchungen durchaus damit vereinbar zu sein.

Resumen

A menudo, el estudio de las dificultades en la lectura desde el punto de vista de la comprensión se ha concentrado en un conjunto de problemas diferente del estudio cuya perspectiva es la identificación de palabras individuales. Sin embargo, según han podido apreciar Perfetti y otros investigadores, estos dos tipos de problemas—la descodificación de palabras y la comprensión de oraciones—pueden estar relacionados de formas diversas. Este trabajo se ocupa de investigar si las principales dificultades a los niveles de la palabra y de la frase (así como de

unidades de texto mayores) tienen una causa común. Indica de qué modo las dificultades existentes en cada uno de ambos niveles pueden derivar de un déficit en la capacidad de procesamiento fonológico, y responde a algunos desafíos empíricos a esta perspectiva con argumentos basados en investigaciones recientes.

Although many in the field of reading research now hold that the causes of reading difficulty are to be found in the language domain, there are significant divisions of opinion concerning where within language the difficulties lie. My purpose in this chapter is to examine these divisions, to explain why it matters how they are resolved, to ask what evidence is pertinent, and to indicate where it leads.

The problem of assigning causes to failures in reading comprehension brings the divisions quickly to the surface. In this regard, a complaint one sometimes hears from reading teachers is that children may fail to comprehend a sentence in text even when they manage to decode all the words it contains. Indeed, the persisting failure of some children to comprehend what they read despite their ability to identify the words has lent credence to the view that, in addition to the difficulties in word decoding that are so apparent in most poor readers, a second set of difficulties may also exist.

How can we best frame those problems of reading that extend beyond the level of the word and assess their contribution to reading disability? Could the problems of comprehension be derived from the same basic limitation that is responsible for word decoding difficulties? I will argue that by investigating how lower-level language abilities are coordinated in reading, we may be able to explain the difficulties at the sentence level in the same terms as the difficulties at the level of the word. In developing our approach to reading difficulties, my colleagues and I have been guided by the possibility that the entire symptom picture in reading disorder, including many comprehension difficulties, may stem from a deficit in phonological processing.

We are aware that some investigators of reading problems will protest that such an account would inevitably fly in the face of the facts. Accordingly, in this chapter I have chosen to concentrate on findings of research that have appeared incompatible with the view that a phonological processing deficit can explain all the difficulties experienced by poor readers. A reinterpretation of these recalcitrant findings is proposed in the light of new experimental results.

Word Decoding and Text Comprehension

First I must clarify what I mean by decoding. It is obvious that comprehending the meaning of sentences and the larger units of text depends on correct apprehension of the individual words. By decoding, I simply mean the process, still incompletely understood, by which the reader identifies the printed words of the text. I am assuming, however, in keeping with the discussion in earlier chapters, that it is an analytic process—that efficient procedures for word recognition recover the linguistic information that the orthography provides. All beginning readers have to learn to identify in print the thousands of words they already know in speech. To succeed at this, the beginner needs to discover that words are phonological structures and to discover how their structures are reflected in their spellings. That is to say, every beginning reader who would ultimately become a good reader must learn to decode. (The first chapter summarized the evidence that poor decoding skills reflect lack of phonological awareness in the disabled reader, and that this problem, in turn, is caused by a wider deficit in phonological processing).

If decoding is a necessary condition for reading, it is clearly not a sufficient condition. In order to comprehend printed matter the would-be reader must also understand how the words of the text function in sentences and how sentences function in paragraphs. That is, a successful reader must parse the component sentences and unpack the argument structure of the text as

a whole. But beginning readers come to the task of reading with a great deal of knowledge of the language already in hand. Through experience with speech, they know how to construct grammatical sentences and how to interpret them. Therefore, it can be argued, as it has been in the words of Gough and Tunmer (1986) that "once the printed matter is decoded, the reader applies to the text exactly the same mechanisms which he or she would bring to bear on its spoken equivalent" (9). On this view, learning to decode is the only new thing a speaker of the language must acquire to become a reader. Consistent with this viewpoint is the fact that a substantial correlation is regularly found between measures of decoding skill and more global reading measures, including measures of comprehension.

Measures of decoding are obtained by having someone read unfamiliar words (and nonwords that are possible words). Several researchers report that in school children these measures account for about half the variance in other measures of reading ability (e.g., Perfetti and Hogaboam 1975; Shankweiler and Liberman 1972; Stanovich 1986; Stanovich, Cunningham, and Feeman 1984). Perfetti (1985) has shown that decoding skills continue to distinguish different levels of comprehension even among adults at the college level, particularly if speed measures are taken as well as measures of accuracy. Even in the early grades, some poor readers who would pass as adequate decoders on the accuracy measure, may, in fact, still be slow and inefficient in decoding. The consistent association between reading measures based on decoding and measures based on comprehension indicates that a beginning reader, to be sure, and sometimes a more experienced reader as well, may encounter comprehension problems due to difficulties in deciphering the words of the text.

Is decoding, then, the only hurdle in learning to read? Some researchers think not, pointing to the existence of "hyperlexic" children who supposedly can decode well and yet comprehend poorly. However, the comprehension problems of these children do not seem to be limited to reading; hyperlexics appear to lack the higher-level language skills required for understanding

verbal material in any form (Healy 1982; Huttenlocher and Huttenlocher 1973). In any case, such children probably constitute only a small proportion of those with reading problems. It is evident that a much larger group of poor readers have problems *both* in decoding and comprehension. Concerning this larger group, it might be supposed that they are beset with at least two deficits, a deficit that impairs apprehension of the individual words and a further independent deficit that impairs their grammatical integration. It would be natural for anyone who believed this to conclude that remedial measures that are directed to the decoding problem would only affect one source of the problems in comprehension. The other source would remain untouched. My coworkers and I, however, have arrived at a different view of the matter. We see the comprehension problems as part and parcel of the difficulties in decoding.

In summary, researchers who agree that the underlying problems in cases of reading disability are in the language domain do not always agree on where within that domain the problems lie or on how many basic problems there are. These researchers divide roughly into two camps on the question of causation. One side supposes that more than one basic deficit must be hypothesized to account for the total symptom picture. The alternative, which I will argue for here, supposes that in at least one major syndrome of reading disability, all the problems of reading spring ultimately from the same source.

Importance of Assessing Comprehension of Spoken Language

To resolve the question, it is necessary to broaden the scope of the investigation of reading problems to include the assessment of spoken language. To make a valid assessment of reading ability, we must examine the reader's comprehension of *both* spoken language and print. Since a failure of comprehension in reading may or may not extend to speech, it is essential to assess comprehension of spoken material before attempting to interpret anyone's failure to comprehend the equivalent material in printed form.

A recent paper by Gough and Tunmer (1986) affirms this important methodological principle. In advancing a "simple theory" of reading, the authors maintain that by measuring only two variables, decoding skill and listening comprehension, we can effectively account for *all* of the variance in reading comprehension. Indeed, they claim that reading skill is adequately described as the product of decoding and listening comprehension. That claim will require a large amount of data to evaluate fully, but let us suppose the simple theory is true and that together these two factors and their product do account statistically for all the variation in global measures of reading ability. If so, many possible causes of reading disability can be ruled out, such as oculomotor and visual perceptual deficits, or a deficit in general analytic ability.

At the same time, the Gough-Tunmer formula can, in principle, explain deviations from the normal course of learning to read. For example, hyperlexics, as we saw, are high on decoding skill, but low on comprehension. Dyslexics, on the other hand, are defined as those poor readers who display the opposite pattern. In contrast, most poor readers arguably have difficulties both in orthographic decoding and in listening comprehension (see discussion later in this chapter). It is apparent, however, that only the decoding problem is specific to reading. If a child fails to understand a sentence in print that would be readily comprehended in spoken form, the failure with print can be considered a failure specifically in reading. But, on the other hand, if the sentence is not comprehended even in speech, then the failure to read the sentence with understanding is wholly predictable from that fact alone. It could hardly be viewed as reflecting a reading problem as such.

The simple theory appeals to those who view reading, as my colleagues and I do, as a bottom-up process with decoding at its core. Insofar as the theory maintains that decoding is a skill that every new reader who would attain mastery must learn, we

heartily agree. But despite this virtue, the simple theory encounters a difficulty in explaining why the children who have decoding problems are so often the very same children who have difficulties in comprehension of spoken sentences. Because the simple theory leaves unexplored the possible causal connections between the factors that limit orthographic decoding and the factors that limit listening comprehension, it can offer no ready explanation for the frequent co-occurrence of both difficulties in poor readers. The theory seems therefore not to encompass the possibility that difficulties in decoding and comprehension may be expressions of a deficit at a single level of language.

The challenge of how to weigh the contribution of poor decoding, how to assess the possible impact of higher-level language deficiencies, and how to properly understand the connection between the two leads us beyond the stage of examining correlations between various measures of decoding skill and global measures of comprehension. To understand the basis of individual differences in each aspect of reading, we need a theory that identifies the components of reading and explains how they are connected with one another and how each one comes into being in the developing child. If we agree that reading is a language skill, it would follow that a theory of reading would have to specify which parts of the language apparatus are needed for reading and how they must be modified to accept print rather than speech as input. This brings us to an examination of learning to read within the larger context of the child's acquisition of spoken language. Building on the framework of theory and method set down in the preceding chapters, I will give an account of reading disability that explains how problems at the word level and the sentence level could stem from a deficit in phonological processing, a deficit that limits both the decoding of printed words in reading and the operations of working memory in the on-line processing of spoken language.

Here, as in the discussion by Crain (in this volume) on the general problem of explaining childrens' failures in language comprehension, it will pay us to distinguish between an account

based on a missing structure and an account based on overloading a language processor. To illustrate the importance of that distinction for developing a causal explanation of reading difficulties, it will be helpful to review findings of pioneering research by Vogel (1975) on the language abilities of good and poor beginning readers.

The study by Vogel, unusually insightful and thorough for its time, attempted a comprehensive assessment of morphological and syntactic abilities in children who differed strongly on standard tests of reading comprehension. Because this study raises several of the issues that concern us throughout this chapter, it is worth examining the findings in some detail. First, good and poor readers were distinguished on some but not all of the language measures. Interpretation of intonation patterns appropriate for statements and questions, verbatim repetition of syntactically complex sentences, tests that require a subject to supply missing grammatical suffixes that mark agreement, and a pair of cloze tests in which the subject listens to text in which every *n*th word is deleted and is required to supply the missing word—each distinguished the reading groups. But also of interest are the tasks on which the groups did not differ. The normal readers and reading disabled children did not differ in accuracy of making grammaticality judgments, or on comprehension of spoken sentences as measured by a picture selection task. But, as Vogel notes, the latter measures had poor reliability and content deficiencies as well, so the failure to find differences between the groups, particularly on the picture selection test, cannot be given much weight.

Appreciating that working memory is a relevant factor in the performance of many language tests, Vogel asked whether the differences between the reader groups that did emerge would remain after contribution of the memory factor was removed statistically. Using scores on digit span and word list recall as covariates, she reevaluated the relation between the "syntax" tests and reading comprehension. The result of the reanalysis was a considerable shrinkage of the correlation between reading com-

prehension and some of the spoken language tasks. The correlations that showed the greatest shrinkage were with the sentence repetition task and the cloze tests. With the contribution of the storage component of working memory removed, cloze performance no longer distinguished the groups; the residual effect of sentence repetition remained significant, though at a reduced level. From this analysis, we discover that short-term retention accounted for much of the variance between the reading groups on some of the so-called syntactic measures. The additional measures that continue to distinguish the groups after the variance due to the memory test was removed are the tests of production of inflected forms and elicited sentence production. Whereas it is clear that these tests tap morphological abilities, it is doubtful that either can be regarded as a test of syntactic ability as such. Indeed, none of the three measures which most sharply distinguished reading disabled from normal readers—two tests requiring production of inflectional suffixes (the Berry-Talbott test and the "grammatical closure" test of the Illinois Test of Psycholinguistic Abilities) and the prosody perception test—could be viewed as a pure measure of syntactic ability. Instead, both tests primarily tap lower-level language abilities (phonological and morphological).[1]

Vogel's study underlines the difficulty of disentangling the contribution of limitations in phonological processing, as revealed in measures of working memory, and limitations of structural knowledge in understanding comprehension difficulties. As I will explain shortly, these factors are often confounded in tasks commonly used to assess comprehension. The main thrust of the research from our laboratory has been directed toward teasing them apart experimentally.

In the past decade, several investigations have focused on comprehension of spoken language by children with reading disability. Although not every study has found unequivocal evidence of differences between matched groups of good and poor readers (e.g., Vogel 1975; Shankweiler, Smith, and Mann 1984), several have found good readers significantly more accurate

than age-matched poor readers in comprehension of some structures in spoken sentences (e.g., Byrne 1981; Mann, Shankweiler, and Smith 1984; Smith, Mann, and Shankweiler 1986). The finding that poor readers do not always comprehend spoken sentences as well as good readers lends support to the possibility that inadequate decoding skill is only one of the barriers to comprehension.

Two Hypotheses about the Causes of Comprehension Difficulties

Two hypotheses have been advanced to explain the difficulties in spoken language comprehension. Taken at face value, the difficulties that poor readers display in interpreting sentences containing complex syntactic structures seem to point to gaps in their structural knowledge. If syntactic structures were missing from their internal grammars, spoken language comprehension would suffer, not just reading. We have called this the "structural deficit hypothesis" (Crain and Shankweiler 1988).

But if we heed the lessons from earlier attempts to test comprehension of complex structures in young children, we would do well to hesitate before drawing firm conclusions about the causes of comprehension difficulties in poor readers. Two caveats should be mentioned. The first is a methodological point: when someone fails to comprehend a spoken sentence with a certain syntactic structure, we cannot, without further analysis, assign a cause to the failure. In chapter 5, it is shown why the data one obtains from a comprehension test are not self interpreting, and why—unless certain precautions are observed—we may be led unwittingly to the wrong conclusions about the source of comprehension difficulty in poor readers. A second caveat reflects assumptions about the structure of the language apparatus. Before we can interpret properly the results of tests intended to measure comprehension, we must appreciate that language understanding, whether of speech or of printed material, is the end result of a complex series of steps. If just one of

the steps goes awry, the understanding may be affected. In presenting a model of the language understanding system, Crain (in this volume) gives reasons for supposing that linguistic information flows through a hierarchy of structures and processors; it is stressed that apprehending the meaning of language input depends on the unimpeded passage of phonological information to the higher-level syntactic and semantic components of the language apparatus.

A further reason for caution in attributing comprehension difficulties to a lag in acquiring the requisite grammatical knowledge is the speed with which children pick up their spoken language. Some researchers on language acquisition believe that almost all of the grammatical structures of the language are already in place by the time instruction in reading usually begins (e.g., see Crain and Fodor, forthcoming). Psycholinguistic studies have demonstrated that the acquisition of language is guided by powerful innate constraints that give rise to impressive uniformities in the course of language acquisition across wide differences in language experience (Wanner and Gleitman 1982). Normal children invariably produce spoken language without direct instruction, much as they learn to walk without being taught. The same can be said of their abilities to understand spoken language. Ordinarily, however, people have to be taught to read. From a biological standpoint, the human species has not evolved special machinery for the perception of print as has evolved for the perception and production of speech.

In view of these considerations, one could well question whether the problem underlying poor readers' comprehension difficulties is likely to be a delay in the acquisition of syntactic knowledge. An alternative hypothesis supposes that the necessary syntactic structures are in place before the child begins to learn to read, and that difficulties in comprehension, both in spoken language and in text, are caused by deficiencies in processing phonological structures. The idea that deficits at the phonological level may underlie all the symptoms of reading disability is supported by evidence reviewed elsewhere in this

volume. In addition to their difficulties in attaining awareness of the phonological structure of words, reading disabled children have a variety of other problems that implicate deficient phonologic processing, including difficulties in naming, difficulties in speech perception and production, and special limitations in working memory. The phonological deficit hypothesis can explain, as I will later show, how these diverse symptoms may reflect a single underlying problem, and it also gives an account of why the affected individuals have difficulty acquiring adequate word decoding strategies. This hypothesis faces its greatest challenge, however, in accounting for comprehension disturbances of poor readers, particularly their difficulties in spoken language comprehension (Shankweiler and Crain 1986).

Experiments on Comprehension of Spoken Sentences by Good and Poor Readers

A review of the relevant research follows next. I will pursue the idea that a deficiency in phonological processing may be the underlying cause of comprehension problems in many poor readers, both in spoken language and in reading. This simplifying perspective on reading disability can prevail only if we can reject the possibility that there are two basic deficits, one at the phonological level and another at the syntactic and/or semantic levels. The following experiments are designed to test between these possibilities.

Sentences Containing Restrictive Relative Clauses

First to be examined are research studies that compare reader groups on comprehension of sentences containing relative clauses. The relative clause has received a good deal of attention, largely because several studies of language acquisition have found that it emerges late in the course of normal development (Sheldon 1974; Tavakolian 1981). The relative clause plays a key role in the sentence grammar: it is a construction that allows the

embedding of one sentence within another. In relative clause sentences, reference must be established between a superficially empty noun phrase in the relative clause and its antecedent noun phrase in the main clause. Coreference relations are governed by constraints involving the abstract structural representation underlying the sentence. These constraints rule out certain coreference possibilities and thereby restrict the semantic interpretations that a sentence can be assigned.

The relative clause has also figured prominently in attempts to assess the grammatical abilities of poor readers (Byrne 1981; Stein, Cairns, and Zurif 1984). It has been claimed that poor readers often have difficulty understanding sentences containing relative clause constructions because of a critical gap in syntactic knowledge. But other interpretations of the difficulties can also be made. Hamburger and Crain (1982) studied very young children's comprehension of sentences containing relative clauses, and gave an account of the extrasyntactic difficulties these sentences may present under varying pragmatic constraints. Among other factors that might be mentioned, their account notes that relative clause sentences may present the perceiver with a problem in *sequencing*. Consider, for example, the following sentence:

The cat scratched the dog that jumped through the hoop.

The second clause denotes an action that ordinarily would *precede* the action denoted by the first clause. Hamburger and Crain found that many children who performed the correct actions associated with sentences like this one, often failed to act out the designated events in the same order as adults. Thus, many three and four year olds acted out the sentence by first making the cat scratch the dog, and then making the dog jump through the hoop. Older children and normal adults typically act out these events in the opposite order, even though this entails acting out the later-occurring relative clause *before* the main clause. Intuitively, this order of events seems conceptually

correct since "the dog that jumped through the hoop" is what the cat scratched. But this order of acting out the clauses would require longer storage of the phonological record. It is possible that the observed difference between the preschool children, on the one hand, and older children and adults, on the other hand, reflects the impact of young children's limited phonological processing capacities on their working memory. (This possibility is considered at the end of the chapter.)

As the example shows, an account of why poor readers have more difficulty than good readers in understanding sentences containing relative clause constructions might also appeal to a phonological processing deficit rather than to a structural lag. To test between these proposals, Mann, Shankweiler, and Smith (1984) conducted an object manipulation experiment with third grade good and poor readers using sentences containing relative clauses. Four types of relative clause structure were tested. In order to assess performance on each type, vocabulary and sentence length were held constant. So, in the sample set below, the same ten words recur in each sentence of the set.

a) The sheep pushed the cat that jumped over the cow.
b) The sheep that pushed the cat jumped over the cow.
c) The sheep pushed the cat that the cow jumped over.
d) The sheep that the cat pushed jumped over the cow.

The syntax varies in two ways—in the place of attachment of the relative clause, whether it is at the subject node or the direct object node, and in the role of the missing noun phrase in the relative clause, which, again, may be either subject or object.

The study by Mann, Shankweiler, and Smith confirmed earlier claims that poor readers can have difficulties in comprehending complex sentences even when they are presented in spoken form. But in several respects the findings invite the inference that the poor readers' problems with these relative clause sentences reflect a deficit in processing and not the absence of critical structures from their internal grammars. First, it was

found that the type of relative clause structure had a large effect on comprehensibility. Sentence types *a* and *d* evoked the greatest number of errors in all the subjects. These are structures that earlier research on younger normal children also identified as the most difficult (Tavakolian 1981). Second, the poor readers made more errors than good readers in comprehension of each of the four types of relative clause structure. But the poor readers did not appear to lack any type of relative clause structure entirely. In fact, their pattern of errors closely mirrored that of the good readers; they simply did less well on each sentence type. This similarity in pattern would be difficult to explain if it were the case that the poor readers lacked one or more of these structures in their internal grammars. Their overall poorer performance would seem to require an explanation in terms of a processing difficulty.

Additional support for the view that the poor readers' difficulties with relative clauses reflect processing factors comes from data on short-term recall that were obtained in the second phase of the experiment by Mann, Shankweiler, and Smith. On a later day the same relative clause sentences were presented to the subjects again, this time for immediate recall. The poor readers made significantly more recall errors than the good readers in keeping with earlier findings on sentence memory (e.g., Perfetti and Goldman 1976; Mann, Liberman, and Shankweiler 1980; Vogel 1975). As was pointed out by Liberman, Shankweiler, and Liberman (in this volume), the deficits poor readers display in working memory are material specific: they have shown up consistently when good and poor readers were tested on a variety of materials that lend themselves to verbal coding, including letter strings, random word strings, and sentences. Nonverbal tasks, such as memory for spatial position, human faces, or abstract designs, do not place the poor reader at a disadvantage (Katz, Shankweiler, and Liberman 1981; Liberman et al. 1982). Findings such as these, when taken together with the data by Mann, Shankweiler, and Smith (1984) on error patterns in comprehension tasks, suggested that phonological processing difficulties,

through their impact on working memory, are responsible for poor readers' failures in comprehension of relative-clause sentences. Thus it is not necessary to assume that incomplete syntactic knowledge is the source of the problem.

This interpretation of the comprehension data, while plausible, was not yet fully substantiated. Challenges that had earlier been raised in the literature had not been entirely dispelled. The question of whether reading disabled children show delayed or deviant patterns of acquisition of relative clause structures was pursued by Stein, Cairns, and Zurif (1984). Using data obtained from an act-out task, their study compared the performance of normal and reading disabled children in interpreting several relative clause structures that were also investigated by Mann, Shankweiler, and Smith (1984). Adopting the theoretical standpoint of staged acquisition of grammatical structures, the authors invoke a procedure that putatively enables one to gauge the stage of a child's grammatical development (Hsu, Cairns, and Fiengo, 1985). The results, like those of Mann, Shankweiler, and Smith (1984), showed that skilled readers performed better than reading impaired subjects, and that the difference was most marked at high levels of linguistic complexity. Application of the metric of grammatical development to the findings led the authors to infer that reading disabled children can be characterized as syntactically deviant from their controls since good and poor readers differed in the order of difficulty of the three relative clause structures that were assessed.

Although these results confirm other indications that poor readers are often not the equals of good readers in performance on comprehension tasks, they do not necessarily mean that poor readers have a deficit in structural knowledge. As we have seen, it is arguable that poor readers do not generally fail to comprehend sentences because of syntactic complexity, as such, but rather because of heavy memory demands that are sometimes confounded with complexity (see Crain and Shankweiler 1988).

Perhaps the strongest support for the view that poor readers'

difficulties with relative clauses reflect processing overload comes from a comprehension study by Smith, Macaruso, Shankweiler, and Crain (forthcoming). This experiment exploits an earlier discovery by Hamburger and Crain (1982) that preschool children's errors in comprehension of restrictive relative clauses are remarkably reduced if, in the design of the test materials, care is taken to meet the presuppositions that the test sentences may evoke. Use of a restrictive relative clause with the definite article often implies that there are at least two objects of a particular category present in the experimental work space, either as props, if the task is a manipulation task, or as pictured objects if the task is a picture-selection test (see example in the next paragraph). The fact that most preschool children (in the Hamburger and Crain study) produced and understood relative clause sentences when the presuppositions underlying their use were satisfied, suggests that failure to meet this requirement in previous studies interfered with children's comprehension of the test sentences. In the case of poor readers, the findings in the literature of impaired performance on comprehension of relative clause sentences might also be tied to excessive processing demands imposed by unmet presuppositions.

To explore this possibility, in the study by Smith et al. (forthcoming) two objects were made available in the experimental workspace to represent the head noun of the relative clause. For the sample sentence shown below, two sheep were placed in the experimental workspace, where only one had appeared in previous studies.

The sheep that the cat pushed jumped over the cow.

Presumptively, the extra sheep was *not* pushed by the cat and did *not* jump over the cow. With this change in place, Smith et al. compared their findings with those of the Mann, Shankweiler, and Smith (1984) study, in which the same subject selection criteria were used, but in which the presuppositions of relative clauses were not met. The data lend strong support to a

processing limitation hypothesis. It was found that both good and poor readers made far fewer errors in the Smith et al. study, in which the pragmatic presuppositions of the restrictive relative clause were satisfied, than occurred in the experiment by Mann, Shankweiler, and Smith (1984) (despite the fact that the subjects of the latter investigation were nearly a year older).

It is apparent that the manipulations of Smith et al. permitted us to pose questions about the children's syntactic knowledge in a way that drastically reduced the nonsyntactic demands. By adopting a procedure that minimizes the processing requirements in a comprehension task, it was found that children with reading disability performed as well as good readers in many instances. We see, then, that the failure in previous work to control for nonsyntactic aspects of sentence comprehension tasks led to underestimates of the grammatical capabilities of reading disabled children. This also holds true of other grammatical constructions as well, as the following examples show.

Sentences Containing Temporal Terms

Sentences that make correct use of temporal terms, such as *before* and *after,* have been found to emerge late in the course of language development (Amidon and Carey 1972). The difficulties children encounter in comprehending temporal terms have been diversely explained in the literature. In keeping with the notion of a structural deficit is the proposal that temporal terms are mastered late because children lack certain structural knowledge that is essential to sentences with subordinate syntax. This interpretation gains support from the finding that children regularly encounter difficulty in acting out temporal term sentences such as *e*, which pose a conflict between order of mention and order of execution. This presents yet another instance of a sequencing problem, such as we examined earlier in certain relative clause sentences.

It is important to note that children do not have difficulty with sentences like *g,* which also pose a sequencing problem.

e) Push the motorcycle after you push the helicopter.
f) After you push the helicopter, push the motorcycle.
g) Push the motorcycle last; push the helicopter first.

Crain suggests that the earlier studies that evoked differential responses to *e* and *g* failed to control for a presupposition present in sentence *e*. The presupposition associated with this sentence is that the hearer intends to push the helicopter. To satisfy this presupposition, the subject's object preference must be established *before* the request in *e* is made. In keeping with this principle, Crain (1982) developed a procedure that requires subjects to establish their intent to perform the action mentioned in the clause introduced by the temporal term. On this procedure, children are asked, before each test sentence is presented, to identify one object they want to play with in the next part of the game. The experimenter subsequently incorporates this information in the subordinate clause introduced by the temporal term. So for example, sentence *e* would have been presented only after a subject had chosen to play with the helicopter, which pragmatically justifies the use of the temporal term (i.e., makes it "felicitous").

Crain has shown substantial gains in children's comprehension of sentences like *e* when the context was made meaningful by eliciting object preferences before testing. This would implicate processing demands, not lack of grammatical knowledge, as a possible reason for the difficulties such sentences pose when they are presented without contextual support. With this background in mind, we anticipated that both good and poor readers would display a high rate of successful comprehension of temporal terms sentences in felicitous contexts, but that the performance of poor readers would suffer in contexts that are not supportive (i.e., when the presupposition associated with the use of temporal terms is not satisfied). However, if the poor readers' difficulties with these sentences are the result of insufficient knowledge of structures, then poor performance should occur with or without contextual support.

We have recently completed a study of good and poor readers' comprehension of sentences containing the temporal terms *before* and *after* (Macaruso et al., forthcoming). Four sentences were presented in which the order of mention of events was the same as the order of execution, as in *f*. In the remaining twelve sentences, order of mention was opposite to the order of execution, as in *e*. As noted above, the sentences were presented both with contextual support (i.e., with object preference preestablished before each test trial) and without contextual support.

Poor readers performed less well overall than good readers in acting out these temporal terms sentences. In addition, the inclusion of contextual support resulted in a significant reduction of errors for both groups. In fact, the poor readers benefited more from the provision of context than the good readers. Poor readers performed with a success rate of 82 percent when the presupposition associated with temporal terms was satisfied. This outcome does not sit well with the syntactic lag hypothesis.

The findings of this experiment indicate that as processing demands are increased, poor readers' performance involving temporal terms is degraded to a greater extent than good readers. Decreasing processing demands by satisfying presuppositions elevates performance of the poor readers to a greater extent than the good readers such that group differences diminish and both reader groups perform with a high level of accuracy.

Detection and Correction of Grammatical Anomalies

In a further attempt to disentangle syntactic knowledge and processing capabilities in beginning readers, Fowler (1988) assessed spoken sentence understanding by means of a task that minimizes processing demands: judgment of sentence grammaticality. The grammaticality judgment task was considered the best available measure of syntactic competence. This expectation is motivated in part by recent research on aphasia which has shown that agrammatic aphasic patients with severe memory

limitations were able to detect grammatical violations in sentences of considerable length and syntactic complexity (Shankweiler, Crain, Gorrell, and Tuller, forthcoming; Linebarger, Schwartz, and Saffran 1983). The findings from aphasia suggest that this task directly taps the syntactic analysis that is assigned.

In addition, Fowler required her subjects to change the ungrammatical sentences in a way that makes them grammatical. The correction task is far more demanding of memory resources than the judgment task. Correcting grammatical anomalies requires the ability to hold sentence in memory long enough for reanalysis.

According to the phonological deficit hypothesis, both good and poor readers should do equally well on the judgment task, but differences between the groups should emerge on the correction task. This was indeed what was found. Reading ability was significantly correlated with success on the correction task, but not with success on the judgment task (in keeping with findings of Vogel 1975, discussed earlier). This result must surely be viewed as support for the hypothesis that processing complexity, and not syntactic complexity as such, is the basis of the comprehension difficulties in poor readers. Further support for this inference comes from the additional finding that results on a test of short-term recall (with the influence of IQ removed) were more strongly correlated with success on the sentence correction task than with success on the judgment task.

Together, the studies we have reviewed confirm the indications of earlier research that poor beginning readers often have significant difficulties in comprehending some spoken sentences. But our research leads us to reject the idea that a syntactic lag is the basis of these comprehension problems. The syntactic lag hypothesis cannot explain the pattern of findings that emerge from these studies. It cannot explain why reader group differences sometimes disappear completely when the critical structures are presented in a way that minimizes processing load, nor can it explain the fact that performance with these structures varies up or down depending on task complexity.

A Phonological Deficit Unites the Difficulties in Comprehension with Those in Decoding

In summary, we have shown how the obtained differences between the reading groups can be explained on the processing limitation hypothesis. First, it was shown that relative clause structures present the same difficulties for reading disabled children as they do for other children, and that the source of the difficulty certain of these sentences pose is pragmatic and procedural, not syntactic. Further, many of the structures that children find most difficult are those that present a problem of sequencing and therefore require the subject to retain the first mentioned clause while acting out the second. It is proposed that poor readers are more limited than normal readers in the memory resources needed to retain phonological information in memory while the correct ordering of events is worked out. That is why we argue that poor readers are particularly prone to error on these sentences (Crain et al., forthcoming). Accordingly, when the experimental context is controlled to minimize processing load, poor readers improve dramatically, sometimes performing as well as good readers (see Smith et al., forthcoming).

A similar line of argument was made for sentences containing temporal terms. Here, too, the difficulty could arise either from syntactic complexity as such or from processing difficulties attendant upon that complexity. It was argued that the difficulties that such sentences present arise, again, largely from the problem of sequencing and the attendant demands on memory. The requirement for retention of phonological information is greater still in the correction task employed by Fowler.

This chapter began with the observation that for some researchers, the problems poor readers evince in decoding words must be explained in different terms than are used to explain their problems in understanding sentences. The first problem appears on the surface to be quite specific to reading: poor readers cannot successfully make analytic use of the orthography to recover the words of the text. The second problem is

apparently broader: poor readers also have difficulties in processing higher-level linguistic information in some sentences, even in spoken language.

Appearances may deceive us, however. The results we have obtained lead us to conclude that *neither* problem is entirely specific to reading—not the problem at the level of the word nor the problem at the level of the sentence. Reading disabled children have difficulties in setting up and using phonological structures and, as is seen throughout this volume, these difficulties manifest themselves in a variety of ways. One manifestation is in the development of decoding skills. Other chapters in this volume examine the evidence that underlying the difficulties in learning to decode, there are a host of phonological deficiencies, some rather subtle, which are revealed through use of appropriate spoken language tasks. Deficits in phonological processing can explain the difficulties poor readers typically experience in learning how to use the orthography. Less obviously, deficits arising from this source can explain poor readers' problems in comprehension, both in reading and in spoken language, as consequences of their effects on working memory.

Having shown by experiments that the syntactic deficit hypothesis cannot in these instances explain the difficulties that poor readers display in comprehension of spoken sentences, we should indicate what considerations lead us to assert that the comprehension problems are a manifestation of phonological processing deficiencies that limit the normal operations of working memory. It must be acknowledged that direct empirical support for this proposal is so far rather limited. So far, few children have been thoroughly studied on both phonological processing tasks and comprehension tasks. But there is another ingredient needed in order to give foundation to a comprehensive theory of reading disability: it will be necessary to amplify and extend the notion of working memory and to explain how the operations of working memory depend on the integrity of phonological processes.

Memory is an essential part of language processing, because language is by its nature sequential: a linguistic message unfolds over time. The pioneering studies of Conrad (1964) and Baddeley (1966) showed that when verbal material, whatever its source, is maintained by rehearsal, the errors reflect phonological properties of the items, rather than some other properties, such as their semantic characteristics. This research led to the general conclusion that the memory system required for integration of words into sentences and larger units of text or discourse relies critically on phonological processes.

An important further development that led to the concept of working memory was stimulated by the need to show how memory is actually used in language processing. An important step in this direction was taken by Baddeley and Hitch (1974) and Daneman and Carpenter (1980), who argued convincingly that the memory system involved in on-line comprehension is not just a storage bin but an operational device. Perfetti and his colleagues have expressed similar views (Perfetti and Goldman 1976; Perfetti 1985). In addition to its storage function, the working memory system also incorporates a control function. In recent papers, several colleagues and I have developed a proposal about how working memory operates in processing spoken language and print (Crain et al., forthcoming; Shankweiler and Crain 1986; Shankweiler, Crain, Brady, and Macaruso, forthcoming). The following is a brief summary of conclusions presented in those papers. As is pointed out in the chapter by Crain (in this volume), the primary function of the control component is to regulate the flow of linguistic information through the interlocking system of parsers. On this proposal, it is the duty of working memory to transfer linguistic information from one component to another of the general language understanding system. That is, one of the jobs of working memory is to transfer phonologically analyzed material out of the limited memory store and push it upward to the syntactic processor, at the same time freeing the storage area to accept the next chunk of phonological material.

Our view of working memory, like the views of others mentioned above, attributes to it both processing and storage functions. Our proposal, however, differs in fundamental ways from

other models in the literature. In keeping with the assumption of the modular organization of the lanaguage apparatus, we conceive of verbal working memory as a specialized device that specifically serves the language apparatus. This distinguishes our proposal from those by Baddeley (1986) and Carpenter and Just (1988). These researchers see working memory as a general purpose device that plays a central role not only in language, but also in problem solving, spatial reasoning, and other diverse forms of complex thinking.

Applying our working memory model to the spoken language comprehension problems of poor readers, we suggested why certain structures are particularly vulnerable to comprehension failure. We explained that many sentences containing relative clauses and some sentences containing temporal terms present a sequencing problem. In the most difficult of these, the clauses have to be acted out in the reverse of their order of arrival. Such sentences exact a heavy toll on working memory because the first clause has to be stored while the second clause is being processed and must remain in storage until a decision is reached about what action is to be performed first. But, as noted, the costs to memory can be reduced by changes in the testing procedure, and it is important that these procedural changes consistently reduced the performance gap between good and poor readers. Thus, the value of this conception of working memory for the analysis of language comprehension problems is that it allows us to make fairly specific predictions about the sentences that will be most costly of memory resources, and, accordingly, will cause the greatest difficulty for anyone with a deficit in phonological processing.

It should be apparent that working memory, on this view, cannot be tested by rote recall tests alone. These tap only the storage component of the system. It has been found, not surprisingly if our view of the complex nature of working memory is correct, that recall measures are sometimes only weakly correlated with measures of reading skill (Daneman and Carpenter 1980). Unfortunately, recall measures are mainly what are available to us in studies comparing good and poor readers.

How Decoding Affects Comprehension

Other things equal, a limitation of working memory stemming from a phonological deficit would have a greater impact on reading than on spoken language comprehension. In spoken language, the phonological structures are extracted from the acoustic signal by the innate speech apparatus that evolution has fashioned to do just that job. But in reading the phonologic information that serves as input to working memory has to be extracted by orthographic decoding routines that, until highly practiced, are inaccurate and slow. In the poor reader, decoding skills remain inadequate as a consequence of their deficiencies in the phonological abilities on which the development of these skills depend.

It is easy to see, on this view, why unskilled decoding is so regularly associated with poor comprehension. The association can be explained on the hypothesis that when the individual words of a text are read too slowly (even if accurately), comprehension suffers because the integrative processes are disturbed. The memory system that is used both in speech understanding and in reading cannot store many discrete items, especially if their order of arrival must be retained. The system can hang on to about five to seven unrelated words before it begins to lose some of them (Miller 1956). Moreover, this form of memory has a very limited survival time; unorganized material can be retained for only a few seconds without continuous rehearsal. Excessively slow decoding constricts the working memory system in failing to recover the phonological segments rapidly enough to permit the sentence parser to function efficiently. Perfetti and Lesgold (1977, 1979) proposed that if the limited working memory resources are used up on getting to the words of the text, there will be insufficient resources left over to support higher-level language processes.

In reading, the transfer of information into and out of the memory store is limited by the level of word decoding skill. If the level of skill is low, all higher-level processes will be depressed. In the worst case, even the simplest sentences would

not be understood. But at intermediate levels of decoding skill, somewhere between the state of the rank beginner and the fluent experienced reader, there will be a gap between what can be understood in print and in spoken form. Unless and until the gap is closed, some sentences will cause more difficulty in print than in spoken form. These are the sentences that, for reasons we have considered, often require reanalysis.

Thus we can readily appreciate the connection between poor decoding and poor comprehension when we see that phonological processing limitations create a kind of bottleneck that limits the assimilation of lower-level language structures into higher-level ones. Because working memory has a small capacity and decays rapidly, it must receive new material at a rate that is neither too fast nor too slow in order to function well in language understanding. Everyone has experienced the difficulties of listening to speech when there are inappropriate pauses between every word. By the time the end of the sentence is reached, the earlier words have faded. Now consider what we know about the unskilled reader. In reading, the decoder works haltingly, in fits and starts. As Perfetti and Lesgold have stressed, the slow rate of input hobbles working memory and creates the bottleneck in moving from words to sentences. Therefore, the meaning is often lost. That, presumably, is the reason why decoding test measures and comprehension test measures are usually significantly associated with one another.

If, as Gough and Tunmer contend, *all* of the variance in reading is attributable jointly to orthographic decoding and listening comprehension, then if variations in each factor stem from the same source, as we have argued, we are in a position to tie together the whole range of difficulties that research finds associated with reading disability. These include difficulties in attaining awareness of phonological segments with attendant failure to grasp the alphabetic principle; difficulties that special testing may bring to light in speech perception, speech production, and naming; and difficulties in managing the working memory on which comprehension both in reading and spoken language depends. Together these symptoms form a syndrome. Each symptom can be regarded as a manifestation of weakness in processing the phonological structures of language (see Crain et al., forthcoming; Liberman and Shankweiler 1985; Shankweiler and Crain 1986).

Why Does It Matter?

An emphasis on decoding in the teaching of beginning reading is natural to those who, like the researchers represented in this volume, think of reading as proceeding essentially in a bottom-up fashion: identifying the words of the text, and their constituent phonological segments, is a necessary prerequisite to comprehending the sentences and the larger units. This perspective, we have maintained, allows reading to share much of the apparatus for spoken language (see Shankweiler and Crain 1986; Shankweiler and Liberman 1976). Once the neophyte reader has constructed new procedures for identifying words in their orthographically coded form, the other parts of the language apparatus could conceivably be taken over intact. Well before the child's first day at school, the higher-level abilities, such as syntax, are already in place and regularly in use in understanding and producing spoken language.

How we view poor readers' failures in comprehension determines the recommendations we make for prevention and treatment of reading problems. If we fail to appreciate the central role decoding plays in reading, we may easily mistake a lower-level processing deficit for a sign of a missing grammatical structure. If we wrongly attribute children's failures to the absence of certain complex syntactic structures, other mistakes may follow: We may be led to make unnecessary text simplifications that rob the language of its vitality and lead to boredom (see Crain and Shankweiler 1988). But if we are correct in our diagnosis that failures in comprehension can often be attributed to limitations of working memory resources stemming from deficits in phonological processing, we can take appropriate steps to reduce the

processing demands of reading texts. These steps would include provision of contextual supports for satisfying the child's presuppositions and scrupulous application to children's reading materials of standards of clarity and style (see Bolinger 1965) that afford protection against the insipidities of "Dick and Jane" primers.

What direct remedial measures can be taken to boost the slow reader? Evidence was reviewed in chapter 1 that the phonological segmentation abilities that underlie word decoding can be successfully taught at any age. Since weaknesses in processing lower-level components in the language hierarchy have important repercussions at higher levels, our first priority must be to strengthen decoding and through practice to develop fluency in recognizing printed words. These measures should do more than anything else to improve reading comprehension by enabling the poor reader to use limited working memory resources efficiently. Only when facility with word identification is attained can the working memory system be used effectively to gain access to syntactic, semantic, and pragmatic structures.

As noted at the outset, it is often argued that an effective approach to research on reading disorders and their treatment must be concerned not only with the problems of learning to read words, but also with comprehension. Taking this concern at face value, it would be hard to disagree. The goal of reading, after all, is to comprehend what is written. Too often, however, an expressed concern with comprehension signals a wish to downplay the importance of decoding. The slogan "reading for meaning" has become a bandwagon on which all the opponents of approaches that emphasize decoding have climbed. The slogan and the polemics that surround it have had an unfortunate result. They have fostered the assumption that an approach to reading that emphasizes comprehension is necessarily at odds with one that emphasizes decoding. A major purpose in writing this chapter was to dispel that misconception and to show that a genuine concern with what limits reading comprehension leads us back to decoding difficulties and their causes.

NOTES

The research discussed in this chapter was supported in part by a Program Project Grant to Haskins Laboratories from the National Institute of Child Health and Human Development (HD-01994). I am grateful to Stephen Crain, Isabelle Y. Liberman, and Paul Macaruso for much valuable discussion and for their insightful comments on earlier drafts.

1. Vogel attempted also to assess which of her language tests were the best predictors of reading comprehension. Unfortunately, the regression analysis designed to answer this question obscures some things that are potentially important because (for purposes of the analysis) the language tests were grouped in such a way that the predictive value of each individual test cannot be assessed independently. Vogel's findings, while generally in accord with other research on the determinants of reading comprehension, are deviant in failing to confirm the predictive value of decoding.

REFERENCES

Amidon, A., and Carey, P. 1972. Why five-year-olds cannot understand *before* and *after*. *Journal of Verbal Learning and Verbal Behavior* 11:417–23.

Baddeley, A. D. 1966. Short-term memory for word sequences as a function of acoustic, semantic and formal similarity. *Quarterly Journal of Experimental Psychology* 18:362–65.

———. 1986. *Working Memory*. Oxford: Oxford University Press.

Baddeley, A. D., and Hitch, G. B. 1974. Working memory. In *The Psychology of Learning and Motivation*, vol. 8, ed. G. H. Bower. New York: Academic Press.

Bolinger, D. 1965. Maneuvering for accent and position. In *Forms of English Accent, Morpheme, Order*, ed. I. Abe and T. Kanekiyo. Cambridge, Mass.: Harvard University Press.

Byrne, B. 1981. Deficient syntactic control in poor readers: Is a weak phonetic memory code responsible? *Applied Psycholinguistics* 2: 201–12.

Carpenter, P. A., and Just, M. A. 1988. The role of working memory in language comprehension. In *The Impact of Herbert A. Simon*, ed. D. Klahr and K. Kotovsky. Hillsdale, N.J.: Erlbaum.

Conrad, R. 1964. Acoustic confusions in immediate memory. *British Journal of Psychology* 3:75–84.

Crain, S. 1982. Temporal terms: Mastery by age five. In *Papers and Reports on Child Language Development,* vol. 21. Stanford: Stanford University.

Crain, S, and Fodor, J. D. Forthcoming. Competence and performance in child language. In *Language and Cognition: A Developmental Perspective,* ed. E. Dromi. Norwood, N. J.: Ablex.

Crain, S., and Shankweiler, D. 1988. Syntactic complexity and reading acquisition. In *Linguistic Complexity and Text Comprehension: Readability Issues Reconsidered,* ed. A. Davison, and G. Green. Hillsdale, N. J.: Erlbaum.

Crain, S.; Shankweiler, D.; Macaruso, P.; and Bar-Shalom, E. Forthcoming. Working memory and sentence comprehension: Investigations of children with reading disorder. In *Neuropsychological Impairments of Short-Term Memory,* ed. G. Vallar and T. Shallice. Cambridge: Cambridge University Press.

Daneman, M., and Carpenter, P. A. 1980. Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior* 19:450–66.

Fowler, A. 1988. Grammaticality judgments and reading skill in Grade 2. *Annals of Dyslexia* 38:73–94.

Gough, P. B., and Tunmer, W. E. 1986. Decoding, reading and reading disability. *Remedial and Special Education* 7:6–10.

Hamburger, H., and Crain, S. 1982. Relative acquisition. In *Language Development,* vol. 1, *Syntax and Semantics,* ed. S. Kuczaj. Hillsdale, N.J.: Erlbaum.

Healy, J. M. 1982. The enigma of hyperlexia. *Reading Research Quarterly* 17:319–38.

Hsu, J. R.; Cairns, H. S.; and Fiengo, R. W. 1985. The development of grammar underlying children's interpretation of complex sentences. *Cognition* 20:25–48.

Huttenlocher, R. R., and Huttenlocher, J. A. 1973. A study of children with hyperlexia. *Neurology* 23:1107–16.

Katz, R. B.; Shankweiler, D.; and Liberman, I. Y. 1981. Memory for item order and phonetic recoding in the beginning reader. *Journal of Experimental Child Psychology* 32:474–84.

Liberman, I. Y.; Mann, V. A.; Shankweiler, D.; and Werfelman, M. 1982 Children's memory for recurring linguistic and nonlinguistic material in relation to reading ability. *Cortex* 18:367–75.

Liberman, I. Y., and Shankweiler, D. 1985. Phonology and the problems of learning to read and write. *Remedial and Special Education* 6:8–17.

Linebarger, M., Schwartz, M., and Saffran, E. M. 1983. Sensitivity to grammatical structure in so-called agrammatic aphasia. *Cognition* 13:361–92.

Macaruso, P.; Bar-Shalom, E.; Crain, S.; and Shankweiler, D. Forthcoming. Comprehension of temporal terms by good and poor readers. *Language and Speech* 32.

Mann, V. A.; Liberman, I. Y.; and Shankweiler, D. 1980. Children's memory for sentences and word strings in relation to reading ability. *Memory and Cognition* 8:329–35.

Mann, V. A.; Shankweiler, D.; and Smith, S. T. 1984. The association between comprehension of spoken sentences and early reading ability: The role of phonetic representation. *Journal of Child Language* 11:627–43.

Miller, G. A. 1956. The magical number seven, plus or minus two, or, some limits on our capacity for processing information. *Psychological Review* 63:81–96.

Perfetti, C. A. 1985. *Reading Ability.* New York: Oxford University Press.

Perfetti, C. A., and Goldman, S. R. 1976. Discourse memory and reading comprehension skill. *Journal of Verbal Learning and Verbal Behavior* 14:33–42.

Perfetti, C. A., and Hogaboam, T. 1975. The relationship between single word decoding and reading comprehension skill. *Journal of Educational Psychology* 67:461–69.

Perfetti, C. A., and Lesgold, A. M. 1977. Discourse comprehension and sources of individual differences. In *Cognitive Processes in Comprehension,* ed. M. A. Just and P. A. Carpenter. Hillsdale, N.J.: Erlbaum.

———. 1979. Coding and comprehension in skilled reading and implications for reading instruction. In *Theory and Practice of Early Reading,* ed. L. B. Resnick and P. Weaver. Hillsdale, N.J.: Erlbaum.

Shankweiler, D., and Crain, S. 1986. Language mechanisms and reading disorders: A modular approach. *Cognition* 24:139–68.

Shankweiler, D.; Crain, S.; Brady, S.; and Macaruso, P. Forthcoming. Identifying the causes of reading disability. In *Reading Acquisition,* ed. P. B. Gough. Hillsdale: N.J.: Erlbaum.

Shankweiler, D.; Crain, S.; Gorrell, P.; and Tuller, B. Forthcoming. Reception of language in Broca's aphasia. *Language and Cognitive Processes.*

Shankweiler, D., and Liberman, I. Y. 1972. Misreading: A search for causes. In *Language by Ear and by Eye: The Relationships between Speech and Reading,* ed. J. F. Kavanagh and I. G. Mattingly. Cambridge, Mass.: MIT Press.

———. 1976. Exploring the relations between reading and speech. In *The Neuropsychology of Learning Disorders,* ed. R. M. Knights, and D. J. Bakker. Baltimore, Md.: University Park Press.

Shankweiler, D.; Smith, S. T.; and Mann, V. A. 1984. Repetition and comprehension of spoken sentences by reading-disabled children. *Brain and Language* 23:241–57.

Sheldon, A. 1974. The role of parallel function in the acquisition of relative clauses in English. *Journal of Verbal Learning and Verbal Behavior* 13:272–81.

Smith, S. T.; Macaruso, P.; Shankweiler, D.; and Crain, S. Forthcoming. Syntactic comprehension in young poor readers. *Applied Psycholinguistics.*

Smith, S. T.; Mann, V. A.; and Shankweiler, D. 1986. Spoken sentence comprehension by good and poor readers: A study with the Token Test. *Cortex* 22:627–32.

Stanovich, K. E. 1986. Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly* 21:360–407.

Stanovich, K. E.; Cunningham, A. E.; and Feeman, D. J. 1984. Intelligence, cognitive skills and early reading progress. *Reading Research Quarterly* 19:278–301.

Stein, C. L.; Cairns, H. S.; and Zurif, E. B. 1984. Sentence comprehension limitations related to syntactic deficits in reading-disabled children. *Applied Psycholinguistics* 5:305–22.

Tavakolian, S. L. 1981. The conjoined-clause analysis of relative clauses. In *Language Acquisition and Linguistic Theory,* ed. S. Tavakolian. Cambridge, Mass.: MIT Press.

Vogel, S. A. 1975. *Syntactic Abilities in Normal and Dyslexic Children.* Baltimore, Md.: University Park Press.

Wanner, E., and Gleitman, L. R. 1982. Language acquisition: The state of the state of the art. In *Language Acquisition: The State of the Art,* ed. E. Wanner and L. R. Gleitman. Cambridge: Cambridge University Press.

CHAPTER 3

Phonology and Reading: Evidence from Profoundly Deaf Readers

Vicki L. Hanson

Abstract

The prelingually, profoundly hearing-impaired reader of English is at an immediate disadvantage in that he or she must read an orthography that was designed to represent the phonological structure of English. Can the deaf reader become aware of this structure in the absence of significant auditory input? Evidence from studies with deaf college students will be considered. These studies indicate that successful deaf readers do appreciate the phonological structure of words and that they exploit this knowledge in reading. The finding of phonological processing by these deaf readers makes a strong case for the importance of phonological sensitivity in the acquisition of skilled reading, whether in hearing readers or deaf readers.

Résumé

Le lecteur d'anglais qui à subi une perte d'audition avant le début de sa capacité de parler a un désavantage immédiat en ce qu'il est obligé de lire une orthographie dessinée à représenter la structure phonologique de l'anglais. Est-il possible que ce lecteur sourd puisse devenir conscient de cette structure dans l'absence de signaux auditoires assez forts? On considérera l'évidence obtenu dans des études avec des étudiants universitaires sourds. Ces études indiquent que les lecteurs sourds qui