588

PHONOLOGY AND THE PROBLEMS OF LEARNING TO READ AND WRITE

Isabelle Y. Liberman and Donald Shankweiler

ABSTRACT

Learning to read and write depends on abilities that are language-related but that go beyond the ordinary abilities required for speaking and listening. Research has shown that the success of learners, whether they are children or adults, is related to the degree to which they are aware of the underlying phonological structure of words. Poor readers are often unable to segment words into their phonological constituents and may have other phonological deficiencies as well. Their difficulties in naming objects and in comprehending sentences, for example, may also stem from a basic problem in the phonological domain.

Memory and Learning Disabilities
Advances in Learning and Behavioral Disabilities, Suppl. 2, pages 203–224.
Copyright © 1987 by JAI Press Inc.
All rights of reproduction in any form reserved.
ISBN: 0-89232-836-3

At the start of formal instruction in reading, the child or adult can speak and understand many words and uncountably many more sentences. Experience tells us, however, that while such command of the language may be necessary for reading, it is not sufficient. But why not? Surely, we must answer that question if we are to understand, and take appropriate action about, the difficulties that so often attend the development of literacy.

Broadly speaking, there are two sets of hypotheses about where the difficulties might lie. One set may be categorized generally as nonlanguage related. Many hypotheses of that kind have been advanced, but perhaps the most widely held (by many clinicans and the lay public, at least) proposes that children who fail have visual perceptual derangements in which they see letters or words wholly or partially backwards. Since the printed word is conveyed to the reader visually, the possibility of some visual defect in the handicapped individual must, of course, be considered. However, we know from the extensive research efforts of many investigators over the years (see Stanovich, 1982, and Vellutino, 1979, for reviews of the evidence) that difficulties in reading are not commonly attributable to perceptual derangements.

Our own research and that of others in the field have persuaded us that learning to read and write depends in large part on special language-related skills that go beyond the primary abilities required in producing and understanding speech. But where in language do those skills lie? Early in our research we guessed that many, perhaps most, are in the phonological domain (Liberman, 1971, 1973), and so we put our attention there. For several reasons, that seemed a plausible guess and, therefore, the right place to start: first, because an alphabetic orthography—the kind we must, as a practical matter, be concerned with—represents the phonology, however approximately; second, because the smooth running of the "higher" processes of syntax and semantics presumably depends, at the very least, on the existence of a proper representation in the "lower" domain of phonology (see Liberman, 1983; Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977, for a discussion of these points). The results of research have, we think, justified our assumptions, providing evidence that characteristics of phonological processing do, indeed, underlie some of the difficulties that poor readers and spellers have. Our aim in this paper is to describe those difficulties and present some of the evidence.

PHONOLOGY AND READING THE WORD

To see what phonology has to do with reading, we must first remind ourselves of what it has to do with language. Perhaps the best way to do that is to imagine what language would be like if there were no phonology. In

that case, each word in the language would have to be represented by a signal (for example, a sound) that differed holistically from the signals for all other words. The obvious consequence would be that the number of words could be no larger than the number of holistically different signals a person can efficiently produce and perceive. Of course, we do not know precisely what that number is, but surely it must be small (especially in the case of speech) by comparison with the tens or even hundreds of thousands of words that a language commonly comprises. What a phonology does for us, then, is to provide a basis for constructing a large and expandable set of words (all the words that ever were, are, and will be) out of two or three dozen signal elements. These signal elements, often called phonemes, are themselves represented (though only after complex transformations) by the sounds of speech.

All this is to say that phonology is real and not invented by linguists, and, more important, that, whatever else they may be, words are always phonological structures. No matter that the meaning of a word, or its grammatical status, is ambiguous, unknown, or subject to dispute; it is always a string of abstract phonological elements, and, within quite narrow limits, all speakers of the language are in close, if only tacit, agreement about the form of that string. It follows, then, that to have perceived or produced a word, however that may be done, is to have engaged a phonological structure. To misperceive or misproduce a word is to have engaged the wrong phonological structure. We take all of that as given by the very nature of language, as distinguished from such other forms of communication like, for example, pictures.

But why, then, should reading words be difficult in an alphabetic orthography, given that such a transcription represents, if only approximately, the phonological structure that the reader must grasp; and what, as a practical matter, can the teacher do about it? We and our colleagues have offered details in earlier papers (Liberman, 1971, 1973, 1983; Liberman, Liberman, Mattingly, & Shankweiler, 1980a; Liberman, Shankweiler, Camp, Blachman, & Werfelman, 1980). Here, it is only appropriate to summarize the argument.

To understand the problem one faces when required to read a word, we must first consider, if only briefly, how the word is perceived when spoken. As we said, the word is formed by a phonological structure, so when the word is perceived, it is this structure that is accessed. But the speaker of the word did not produce the phonological units one at a time, each in its turn, that is, did not spell the word out aloud. Rather, the speaker "coarticulated" the phonological units (i.e., assigned the consonant we know as 'b,' for example, to the lips, and the vowel we know as 'a,' for example, to a shaping of the tongue, and then produced the two at pretty much the same time). The advantageous result of such coarticulation is that speech proceeds at a satisfactory pace (have you ever

tried to understand speech when it was spelled to you, letter by painful letter?), but a further result, and a less advantageous one for the would-be reader, is that there is now, inevitably, no direct correspondence in segmentation between the underlying phonological structure and the sound. Thus, though the word "drag" has four phonological units and, correspondingly, four letters, it has only one pulse of sound, the four elements of the underlying phonological structure having been thoroughly overlapped and merged. How, then, do listeners recover the discrete units of the phonological structure from the seamless sound, thereby making contact with the word as it must be stored in their lexicons?

The long and comprehensive answer has been provided in other papers from our laboratory (see in particular A. M. Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; A. M. Liberman & Mattingly, 1985; A. M. Liberman & Studdert-Kennedy, 1978). The short and, for our purposes, sufficient answer is that the phonological segments are recovered from the sound by processes that are deeply built into the aspect of our biology that makes us capable of language. This is to say that in listening to speech, the processes by which we perceive the phonological structure conveyed by speech go on automatically, below the level of conscious awareness. In listening to speech, we are no more consciously aware of the processes by which we arrive at the word than we are consciously aware in vision of the way we use binocular disparity to perceive the relative distance of objects in our field of view.

But reading is different in that it is, in some significant measure, a secondary, less natural, use of language—part discovery, part invention. It follows, then, that even though its processes must at some point make contact with those of the natural and primary system, special skills are required if the proper contact is to be made. We take the point of that contact to be the word, which is, of course, represented in the print by a transcription of the phonological structure. But this transcription will make sense to the child only if he or she understands that it has the same number of units as the word. Only then will the relation between the print and the word be apparent.

Thus, readers can understand, and properly take advantage of the fact, that the printed word *drag* has four letters, only if they are aware that the spoken word "drag," with which they are presumably already quite familiar, is divisible into four segments. They will probably not know that spontaneously, because, as we have said, the relevant processes of speech perception, which they already command, are automatic and unconscious. And it may be somewhat difficult to teach them what they need to know because, given the overlap of phonological information that characterizes the spoken word, there is no way to produce the consonant segments in isolation. The teacher can try, of course, to "sound out" the word, but

in so doing will necessarily produce a nonsense word comprising four syllables, "duhruhahguh." Such instruction may be better than none at all, but it may not help the child understand why it makes sense to represent the meaningful monosyllable "drag" with four letters. In the next sections, we offer some of the evidence which shows that novice readers do indeed find it hard to see why, and, further, that their difficulty in this regard is associated with poor reading ability.

Awareness of Basic Phonological Structure

We know that the child's awareness of phonological structure does not happen all at once, but develops gradually over a period of years. Some 12 years ago, we began to examine developmental trends in phonological awareness by testing the ability of young children to segment words into their constituent elements (Liberman, Shankweiler, Fischer, & Carter, 1974). We found that normal preschool children performed rather poorly. We learned, however, as we had suspected, that of the two types of sublexical phonological units, syllables and phonemes, the phonemes presented the greater difficulty. None of the 4 year olds whom we tested could accurately count the number of phonemes in familiar monosyllabic words, though about half managed an accurate count of syllables in multisyllabic words. At the age of 5 years, a similar pattern emerged: Over half succeeded in the syllable task but less than a fifth could achieve phoneme counting. Only 10% failed the syllable counting task at the end of the first school year, whereas 30% were still failing phoneme counting.

It was clear from these results that awareness of phoneme segments is harder to achieve than awareness of syllable segments, and develops later, if at all. More relevant to our present purposes, it was also apparent that a large number of children may not have attained either level of understanding of linguistic structure (phoneme or syllable) even at the end of a full year in school. We turn now to the evidence that awareness of linguistic structure, which so many children lack, may be important for the acquisition of reading and spelling.

Awareness of Phonological Structure and Literacy

Much evidence is now available to suggest that awareness of the phonological constituents of words (or as it is sometimes called, metalinguistic awareness) is most germane to the acquisition of literacy. This evidence comes from studies, including some that have been carried out in languages other than English, which have shown that this awareness is predictive of reading success in young children (Alegria, Pignot, & Morais, 1982; Bradley & Bryant, 1983; Liberman, 1973; Lundberg, Olofsson, & Wall,

1980; Mann & Liberman, 1984; deManrique & Gramigna, 1984; Treiman & Baron, 1981). One study worthy of special mention as one of the most extensive was carried out in Sweden (Lundberg, Olofsson, & Wall, 1980). Among the many abilities, both related and unrelated to language, considered in that study, the ability to segment words into phonemes was the single most powerful predictor of future reading and spelling skills in a group of children tested at the end of their kindergarten year.

A more modest but similar study from our laboratory (Mann & Liberman, 1984) was a longitudinal comparison of a group of children as kindergarteners and first graders. It had the aim of discovering the best kindergarten predictors of reading success. The ability to segment words by counting their constituent syllables was selected instead of phoneme counting as the measure of awareness. We knew, given the results of our earlier study, that syllable segmentation ability (unlike phoneme segmentation) was already in place in over half of the children before the first grade; therefore, we considered syllable awareness would be less open to criticism as possibly confounded by reading instruction. Of the 26 children later classified as good readers in the first grade, 85% had "passed" the syllable counting test when they were kindergarteners. In contrast, only 56% of the average readers and 17% of the poor readers had been successful.

In a recent study by our research group (Liberman, Rubin, Duques, & Carlisle, 1985) metalinguistic awareness in the phonological domain has been found to be also highly predictive of spelling success. This study relating the invented spellings (Read, 1971) of kindergarteners to their performance on other language-related tasks suggests that their proficiency in spelling is more closely tied to phonological awareness than to other aspects of language development. Of the eight language-based tasks administered to this group, three made a difference statistically and accounted for 93% of the variance in invented spelling proficiency. These three unquestionably tapped phonological skills. Listed in descending order of importance, they included a phoneme analysis test patterned after Lundberg et al. (1980); a test of the ability to supply the correct grapheme when phonemes are dictated; and a test of the ability to delete phonemes from spoken words, adapted from the Test of Auditory Analysis Skills (Rosner, 1975). A fourth, a picture naming test, contributed 1% to the variance but did not quite attain significance. It is less obviously phonological in nature, but, as we shall note in a later section, it may be viewed as a subtle indicator of phonological difficulties. The four remaining language-based tasks did not make a difference in the kindergarteners' performance on the invented spelling test. It is notable that though these four tasks all reflect certain aspects of language development, they do not require the degree of awareness of internal phonological word structure that is tapped

by the others. Three of these tasks (receptive vocabulary, letter naming/writing, and word repetition) do not include the analytic phonological component at all; the fourth (syllable deletion) taps it at a less abstract level closer to the basic unit of articulation.

These results and the many others that could be cited (Blachman, 1983; Fox & Routh, 1980; Goldstein, 1976; Helfgott, 1976; Zifcak, 1981) certainly suggest that readiness for reading and spelling is related to metalinguistic awareness of the internal structure of words. There is now some evidence that this relationship also implies that phonological awareness may help the child learn to read. This evidence comes from a pair of experiments (Bradley & Bryant, 1983), the first of which looked at the performance of a large number of 4- and 5-year-olds, none of whom could read, on a metalinguistic task requiring categorization of the "sounds" (phonemic constituents) in words. As in previous studies, high correlations were found between phonological awareness (in this case measured by the sound categorization scores) and the children's reading and spelling scores 3 years later. The relationship remained strong even when the influence of intellectual level at the time of the initial tests was removed.

However, as the authors themselves correctly point out, simply to show that children's skills in metalinguistic awareness are predictive of their success or failure in reading later on does not by itself prove that the relationship is necessarily a causal one. It is possible, in principle at least, that the measured relationship occurred because both abilities are highly correlated with a third ability and that this unidentified third ability is the controlling factor. In order to get around this problem, the authors carried out a second experiment. This was a training study using subsamples of the original group, carefully matched for age and IQ, but with initially low scores on phonological judgments. For one subgroup, the training sessions directed the child's attention to shared initial, medial, and final phonemes in consonant-vowel-consonant words. A second group was also taught this information, but in addition was shown how phonemes in the test words could be represented by letters of the alphabet. A third group received instruction in semantic classification of the same set of words, but no attention was given to the phonological relationships or the spelling. As a control, a fourth group received no special training at all. It was found at the end of the project that the children receiving training in phonological categorization were superior to the semantically trained group on standardized tests of reading and spelling, and those trained with alphabetic letters in addition to the phonological training were even more successful (particularly in spelling).

Together, this pair of experiments, which combines longitudinal and training procedures, offers the strongest evidence to date of a possible causal link between phonological awareness and reading and writing abil-

ities. At the very least, they support other studies showing that there are methods for training phonological awareness that can be used successfully with young children (Content, Morais, Alegria, & Bertelson, 1982; Olofsson & Lundberg, 1983). Beyond that, they also indicate that this training can have beneficial effects on children's progress in learning to read and spell (see Vellutino, in press, for another phonological training procedure with salutary effects on literacy).

There remains some question, however, concerning the extent to which phonological awareness, which we have seen to be important for reading and spelling success, arises spontaneously, as it were, as part of general cognitive development, or whether, alternatively, it develops only after specific training or as a spinoff effect of reading instruction.

The question as to whether word-related metalingustic abilities develop spontaneously or must be taught is a crucial one, with obvious implications not only for preschool instruction, but also for the design of literacy teaching programs geared to adults. It was explored in an unusual investigation by a group of Belgian researchers who examined the phonological awareness of illiterate adults in a rural area of Portugal (Morais, Cary, Alegria, & Bertelson, 1979). They found that the illiterate adults could neither delete nor add phonemes at the beginning of nonsense words, whereas others from the same community who had received reading instruction in an adult literacy class succeeded in performing those tasks. The authors concluded that awareness of phoneme segmentation does not develop spontaneously even by adulthood, but arises as a concomitant of reading instruction and experience. A closer look at the results reveals that within the literate group, those who had obtained certificates for passing the course performed significantly better on the measures of phoneme segmentation skill than those who had taken the course but had not attained the level of proficiency required for a certificate. This kind of variation should not, of course, be ignored. It is entirely plausible that those adults who took the course and did not do well may resemble younger poor readers in other studies: Their failure to develop awareness of phonological structure may have hindered them in learning to read.

Another relevant study is one recently carried out in mainland China with subjects grouped according to whether they had or had not ever been exposed to alphabetic instruction (Read, Ahang, Nie, & Ding, 1984). The results of this study again suggest that reading instruction may be a critical factor in developing phonological awareness. The critical finding is that given a phoneme addition-deletion task (similar to that used with the Portuguese subjects), individuals who at some time in their educational experience had been exposed to *pinyin*, the official alphabetic spelling system, performed that task very well. In contrast, those whose only literacy training had been in the Chinese logographic characters and who had had

no experience with the alphabet did not. Thus, it appears that people who are literate but who have not developed alphabetic literacy may not develop a metalinguistic strategy at the phoneme level.

In view of these findings, we believed that it should prove of value to explore further the cognitive characteristics of adult poor readers. In previous work, we had concentrated on children who were having difficulties learning to read. Now, we proposed to examine the characteristics of adults who despite years of exposure to alphabetic reading instruction as children had not achieved full literacy. We were interested in particular to learn whether their performances would be similar to those of younger learners who were having difficulty. We consider a recent study of a community literacy class that was conducted by members of our research group (Liberman, Rubin, Duques, & Carlisle, 1985) as only a first step toward that goal, but one that nonetheless provides promising leads.

In a comparison of the reading and spelling of our adult subjects, we found, as would be expected in any comparison of recognition and production measures, that their reading of single real words was better than their spelling of such words. But on nonsense words, for which some explicit reference to the phonological structure is obligatory rather than optional (as it may be in dealing with real words), the advantage of recognition over production was eliminated. The performance of the adults on both reading and spelling of nonsense words was quite poor and virtually identical in quality, bespeaking what seemed to be a serious deficiency in the ability to deal analytically with phonological structure.

The performance of the adult poor readers in another task, one directly measuring language analysis at the phonemic level, lends credence to the hypothesis that they may indeed have such a deficiency. On a very simple phoneme analysis task requiring only that subjects identify the initial, medial, or final sound in words (an exercise commonly encountered in first-grade classrooms), they managed to produce correct responses on only 58% of the items. Moreover, they clearly found the task particularly frustrating and unpleasant. This inability of adults with literacy problems to perform well on tasks requiring explicit understanding of phonological structure has also been found by other investigators (Byrne & Ledez, 1983; Marcel, 1980; Morais et al., 1979; Read & Ruyter, 1985).

A recent study of adult prisoners of low literacy (Read & Ruyter, 1985) provides strong confirmation of these pilot findings of ours. In their report of this new investigation, the authors note that their subjects remain poor readers despite cognitive maturity, environmental experience with the written language, and adequate general intelligence. The greatest difficulty displayed by these adults is in decoding unfamiliar words and in the segmentation skills that underlie decoding—particularly in tasks that demand awareness of the location of phonemes within a syllable. The subjects are

much better at recognizing familiar words and also in tasks that do not require internal phonemic analysis, such as identifying the initial consonant and judging overall similarities in words. The authors remark that whatever the causes of the difficulty (poor educational opportunity and/or motivation), a prominent characteristic now is a disability in decoding new and unfamiliar words and in phonemic segmentation. Moreover, the deficits clearly cannot be attributed to a general maturational lag, for they do not disappear in these adults of adequate intelligence.

Despite much evidence of the kind we have been considering here, there remains a question as to whether the deficiency may be in fact not necessarily phonological, or even linguistic, but rather attributable to a deficiency in general analytic ability (Wolford & Fowler, 1983). This question is addressed directly, and, in our view, very convincingly, in a recent study by the Brussels group of experimenters. They have recently shown (Morais, Cluytens, & Alegria, 1984) that poor readers (children aged 6 to 9 years with severe reading disability) were poorer than normal readers in segmenting words into their constituent parts, but performed as well as normal readers in a similar task that required them to deal not with words but with musical tone sequences. Thus, evidently the deficiency that the poor readers were exhibiting was not due to a general analytic disability, but was rather specifically language-related and, more than that, specifically phonological in nature.

The possible presence in poor readers of a general analytic deficiency rather than a deficiency specifically in the phonological realm was a question also addressed in yet another recent study (Pratt, 1985). There two complementary experiments were carried out—one with good and poor readers in adult education classes and the other with good and poor readers in the third grade. Both reader groups in each case were given linguistic awareness tasks and a nonspeech control task identical in format to one of the linguistic tasks. Significant differences between the good and poor readers at both levels were found on all three linguistic awareness measures but not on the nonspeech control task.

Thus, it appears again that the deficiency the poor readers were exhibiting was not due to some general analytic disability, but was, instead, specifically language-related and, more than that, specifically phonological in nature.

As we have seen, there is now a wealth of evidence pointing to metalinguistic deficiencies in the phonological domain in individuals of various ages, languages, and cultural backgrounds, who have difficulty in attaining literacy. We suggest that perhaps it would be reasonable now to consider seriously the possibility that the deficiency in these individuals who are resistant to ordinary methods of literacy instruction may not be limited

to metalinguistic awareness, but may reflect a more general deficiency in the phonological domain. Some of the evidence for this conjecture is discussed in the next two sections.

PHONOLOGY AND NAMING

We now turn to consider the significance of the well-known fact that children who are poor readers often have some degree of difficulty in producing the names of things. At first blush, this would appear to be a problem completely separate from their difficulties in reading. But, in our view, the failures in calling up the appropriate name of an object and the failures in identifying words in print may both relate in some degree to the poor readers' difficulties with language at the level of the phonology.

Several investigators have found that errors in naming are characteristic of children with reading disability (Denckla & Rudel, 1976; Jansky & de Hirsch, 1973; Katz, 1986; Mattis, French & Rapin, 1975; Wolf, 1981). The existence of a naming problem can be demonstrated by a picture naming test of the sort that is commonly used in testing aphasic patients. The data we discuss here were obtained using an adaptation of the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1976), in which the subject is presented with pictured objects one at a time and is required to name each item as it appears.

The fact that poor readers tend to misname things could lead one to infer that the problem is semantic. But, as we shall see, this may be a wrong inference. The first step toward a correct analysis of the poor reader's naming difficulties is to recognize that there are several different aspects to the naming task. First, the perceiver has to apprehend the object in perception. The object must be recognized for what it is. Then a search of the internal lexicon must be carried out to find the word that best names the object. Finally, the word must be articulated in overt speech. An error can arise at any stage from perceptual apprehension to phonetic output. Thus, an error in naming does not automatically reveal its source, which can only be discovered by further analysis.

The experiments needed to pinpoint the source of mistakes in naming have rarely been carried out. Katz's (1986) study is noteworthy in this regard. Words selected for the study were pictured items from the Boston Naming Test that were considered appropriate for children aged 8 to 10 years. High-frequency and low-frequency words were equally represented in this revised version of the test.

In tabulating the results, Katz noted the relationship between each naming error and the target word (i.e., the word judged to be the best

name for the object depicted). He showed that although the poor readers produced more incorrect names than the good readers, their responses were not arbitrary. Indeed, they often resembled closely the phonological structure of the correct word. For example, when the picture presented was of a globe, one child's response was to produce the nonword, "gloave" which, though incorrect, is identical to the target word except in the last phonological segment. Such an error is consistent with the hypothesis that the child has identified the object in question, but has difficulty producing the word.

In other cases, the child produced a real word in response to the test picture. Again, the response often bore a close phonological resemblance to the target word phonologically. Thus, a frequent response to the picture of a volcano was the word, "tornado"—quite different in meaning but with the same number of syllables, an identical stress pattern, and similar vowel constituents. Without further tests, however, the interpretation of such a response would be ambiguous. Katz resolved these ambiguities by questioning the child. When, in this instance, the subject was subsequently quizzed about the characteristics of the pictured object, he correctly described a volcano and not a tornado. Thus, it was clear that the child was quite aware of the meaning of the object. Many other cases in which an ambiguous response was produced were resolved similarly: It often turned out that the child's problem had to do not with meaning, but with the phonological structure of the target word. Thus, whether the poor readers' responses were nonwords (as in the first example) or incorrect real words (as in the second example), the source of the error was often phonological.

Further indications that phonology and not semantics may have been at the basis of these poor readers' naming errors are provided by the results of a test of identification of pictured objects in which the previous procedure was reversed. In this reversed procedure, the examiner produced the name and the child had to select the one picture from a set of eight that best depicted the meaning of the word. Each item that had previously been misnamed on the naming test was subsequently tested for recognition in this manner. In most cases, correct retrieval was demonstrated. Thus, it was apparent that the poor readers had acquired internal lexical representations of most of the objects whose names they could not produce accurately. As Katz (1986) points out, distorted production of the word for an item that has been correctly identified could stem either from an incomplete specification of the phonological word in the lexicon, or from deficient retrieval and processing of the stored phonological information. Which of these possibilities is correct is not relevant to the question at issue here. What is relevant is that, in either case, the source of the poor readers' difficulty had to do with the phonologic aspect of words and not with their meanings.

PHONOLOGY AND SENTENCE COMPREHENSION

Having seen that deficiencies in the phonological domain may be responsible for difficulties in reading words, and also for some of the well-known problems of naming, we turn to the role of phonological abilities in sentence comprehension. Recent investigations have noted that poor readers frequently have difficulties understanding complex sentences, not only in reading but also in speech (Byrne, 1981; Vogel, 1975). Our principal task in this section is to say why one would suppose that the deficit that underlies poor readers' difficulties in sentence understanding is phonologic, and how we have gone about testing this idea.

We begin by making three points: First, understanding sentences requires short-term memory. Second, short-term memory depends on the ability to exploit phonologic structure. Third, young children who are poor readers are known to have special limitations in short-term memory and deficiencies in the use of phonological structure. We take up each of these points in turn and attempt to show the connections between them. First, we discuss how short-term memory is relevant for comprehension; then we suggest how the short-term memory system depends on phonological structures; and finally we introduce evidence that the comprehension problems of poor readers may stem not from lack of syntactic abilities but from weaknesses in the phonologic system.

It has been suggested that short-term storage must play a central role in the operation of the syntactic and semantic processors because ascriptions of syntactic structure and propositional content must be based on briefly holding sequences of words in memory (Liberman, Mattingly, & Turvey, 1972). Thus, verbal short-term memory is needed for processing connected discourse, whether it is apprehended through the medium of the printed page or by speech. Although use of short-term memory is not unique to reading, we argue that reading may place special demands on this system.

The hypothesis regarding need for short-term memory might seem to be weakened by recent data from several sources indicating that the processes supporting sentence comprehension are to a considerable extent performed "on line" (e.g., Frazier & Fodor, 1978; Frazier & Rayner, 1982). Partly in response to such findings, most recent current conceptions of sentence parsing mechanisms have the parser operating on small chunks of the text (groups of two or three words). In our view, these developments actually strengthen the argument that short-term memory is essential to ongoing language processing. It is precisely because this memory system has such a limited capacity for retention of the verbatim record that fast-acting processing routines must have evolved (Crain & Shankweiler, in press). There is much evidence that the temporary memory system, on

which the processing of connected language depends, briefly preserves the phonology and its phonetic derivatives; short-term memory is thus said to depend on an internal phonetic code (Conrad, 1964, 1972; Crowder, 1978).

In relating this information about memory to the performance of beginning readers, it is significant, first, that the memory deficits of young children who are poor readers appear to be limited, by and large, to the linguistic domain. For example, we have found that they have no more difficulty than good readers with memory for faces, nonsense designs, and other stimuli not amenable to verbal labeling (Katz, Shankweiler, & Liberman, 1981; Liberman, Mann, Shankweiler, & Werfelman, 1982). In addition, there is reason to believe that poor young readers are specifically deficient in use of the short-term memory code. Thus, it has been found that poor readers in the early elementary grades who perform poorly also on tests of immediate recall do not code the phonetic properties of words as fully as good readers (Brady, Shankweiler, & Mann, 1983; Liberman et al., 1977; Olson, Davidson, Kliegl, & Davies, 1984; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979).

Considerable evidence already exists pointing to a connection between poor readers' difficulties in remembering sequences of spoken words (and other materials that can be coded as words) and their failure to exploit phonological structure as a vehicle for short-term retention (Mann, Liberman, & Shankweiler, 1980). The suggestion has also been made (Byrne, 1981; Mann et al., 1980; Shankweiler et al., 1979; Vellutino, 1979) that short-term memory limitations might account as well for the problems poor readers sometimes display clinically in oral sentence comprehension. This possibility was strengthened by the finding that poor readers are worse than good readers not only in recall of arbitrary strings of words, but also in recall of both meaningful and meaningless (but syntactically accurate) sentences (Mann et al., 1980).

Until a recent study by Mann, Shankweiler, and Smith (1984), however, no experiment had expressly addressed the question of whether the sentence comprehension problems of poor readers might not be to some degree phonologic in nature, rather than syntactic. The test of syntactic competence selected to make this determination tapped the subject's understanding of relative clauses. The relative clause, which allows the embedding of sentences within one another, was chosen because it is a device of central importance to grammatical function. Syntactically complex, it is apt to be misinterpreted by young children (Tavakolian, 1981) and also by older persons with language disorders (Caramazza & Zurif, 1976).

Good and poor readers in the third grade were tested for comprehension of four different orally presented relative clause structures. In constructing

the test sentences, account was taken of the grammatical fact that a relative clause may attach either to a subject noun phrase or to a direct-object noun phrase, and, further, that the relative pronoun that substitutes for the missing noun phrase (in the relative clause) can take either the subject role or the direct-object role.

Comprehension of the tape-recorded sentences was tested by the children's manipulation of toy animals. Rote recall for the sentences was also tested, but on a later day; the children listened to the recordings again and were asked to repeat each sentence as accurately as possible. The pattern of errors for good and poor readers in comprehension and recall for each type of relative-clause sentence was then examined. One way an error of sentence interpretation can arise is from simplification of the structure of a sentence containing a relative clause. For example, the sentence might be interpreted as having two main clauses joined by *and* rather than having a relative clause modifying a noun phrase. Such an erroneous parsing of a sentence containing an object-relative clause, as in the example, "The dog stood on the turtle that chased the sheep," would result in a response by the child in which the dog stands on the turtle and chases the sheep. If it were found that poor readers made chiefly this kind of error, it could be taken to imply that their grammar is less differentiated than that of normal adults and more mature children of their own age. Such a finding would constitute evidence of a primary deficiency in syntactic competence. But, in the event, that is not what happened.

Turning to the results of the test of comprehension, we consider first the errors for each of the four sentence types, separately for good and poor readers. It was found that the poor readers made consistently more errors than the good readers. It was expected, on the basis of past research on language acquisition (Tavakolian, 1981), that there would also be differences in difficulty among the sentence types, and, in fact, such differences were found even in children as old as these (8 to 10 years). But when the four sentence types were ranked in order of difficulty for good and poor readers separately, the ordering was found to be the same for both groups. The poor readers were generally worse than the good readers in comprehension of relative clause sentences, but within this broad class, they were affected by syntactic variations in the same way as the good readers. The results give no evidence, then, that the poor readers were deficient on any facet of the grammar pertaining to the interpretation of these relative clause sentences. The competence they displayed in this regard was essentially like that of the good readers. A similar result was obtained in a second experiment on interpretation of reflexive pronouns that employed the same subjects (Shankweiler, Smith, & Mann, 1984).

We must account, however, for the other major finding of the study: The poor readers' performance, though similar in pattern, was not equiv-

alent in proficiency to that of good readers in comprehension of any of the four relative clause structures. The best clue we have as to why the poor readers were less accurate is given by comparing their performance on the test of rote recall, where it was found that the poor readers also made significantly more errors. Again, the differences between the groups did not favor one type of sentence more than another. When the recall scores and the comprehension scores on individual subjects are compared statistically, a significant degree of correlation is found. These results are also in complete agreement with recall findings obtained earlier (Mann et al., 1980) with comparable groups of good and poor readers. They fit well with much earlier work that indicates, as we have seen, that poor readers perform consistently more poorly than good readers on a variety of tests of verbal short-term memory. Thus, the failure of the poor readers to do as well as the good readers on the test of sentence comprehension is probably a reflection, at least in part, of verbal short-term memory deficiencies in the poor reader group.

Although these studies do not totally resolve the question of whether the poor readers have a deficit in syntactic competence as such, there is nothing in the findings that would specifically indicate such a deficit. Instead, the findings suggest that our disabled readers have acquired the grammar they need for understanding these complex sentences, though they do not always interpret them correctly. When they deviate from good readers, it would appear to be because they cannot remember the words and their order of occurrence as well. Thus, the findings we have to date support the claim that the poor readers' difficulties in comprehension may ultimately stem from failure to exploit the phonological structure in short-term memory. Therefore, we would suppose that the difficulties in understanding sentences, like the difficulties in reading words and naming objects, are at root phonological.

The phonological deficiencies we have uncovered in poor readers' performance on tasks involving spoken language have definite consequences for reading, and it is to reading comprehension itself that we now turn. It is important to appreciate that the problems that poor readers characteristically have in comprehension of text stem in large part from their slow and inaccurate word decoding skills. Because short-term memory is, for everyone, both fleeting and limited in capacity, the rate at which material is read into short-term memory is critical. Perfetti and his colleagues (Perfetti & Hogaboam, 1975) have suggested that poor readers cannot use their short-term memory efficiently because of the "bottleneck" created by slow word recognition. Thus reading sentences with comprehension would be hampered, even if all the component words were identified correctly, but too slowly to be processed efficiently. The problem is even more serious, however, than we have indicated so far. Poor read-

ers, as we have seen, have not just the normal limitations of short-term memory; their short-term memory spans are abnormally curtailed. Therefore, poor readers' problems in reading complex sentences may be especially acute.

The point that we would add to this account of the bottleneck hypothesis is that, in view of the findings of Mann et al. (1984), we do not have to invoke a syntactic deficit in order to account for problems in reading sentences. We see that a low-level deficit in use of the orthography to gain access to word representations may have major repercussions on the higher-level syntactic and semantic processes required for text comprehension, especially when compounded by a short-term memory problem. Our research leads us to believe that reading comprehension difficulties may reflect processing limitations originating in the phonology, and not necessarily absence or malformation of the higher level structures of the sentence grammar.

SUMMARY AND CONCLUSIONS

In our research we have sought to identify the language-related sources of difficulty in learning to read and write. To this end, we have explored the difficulties of poor readers in reading words, in naming, and in sentence comprehension. First, we discussed evidence suggesting that it is difficult for the beginning reader to grasp that words have parts: phonemes, syllables, and morphemes. A language user does not need to be aware of what the parts are in order to speak and understand speech because the built-in speech apparatus processes them automatically. But to learn to use an alphabet, to read and to spell, the learner needs to become aware of the parts to make the connection between speech and writing. Awareness of sublexical structure draws upon a set of phonological (or, more accurately, morphophonological abilities [Liberman et al., 1980a]). Possession of these abilities distinguish people who are good readers and spellers from those who are less skilled. Though native abilities may account to a considerable degree for the differences, experience in reading and writing also plays a significant role.

Poor readers not only have problems in identifying printed words, they also frequently have problems finding the most appropriate words for things in speaking. By quizzing poor readers about the objects they misname, it has been learned that the source of the naming error is not always a semantic confusion. Frequently, the source of the problem is not having ready access to the mental structures that store information about the phonological properties of particular words in the vocabulary (Katz, 1986).

In the last section of the paper we showed that difficulties in the phonologic domain are sufficient to cause problems in sentence understanding. In order to process complex sentences accurately, one needs to have the ability to retain the words of the sentence and their order, briefly, while the information is processed through the several levels from sound to meaning. Poor readers do not remember ordered series of linguistic items (words and objects that can readily be coded as words) as well as good readers. Their special-purpose phonetic working-memory system is deficient. This is probably not a general cognitive deficit, since nonlinguistic memory tests do not distinguish poor readers from good readers. The processing limitation, which is apparently specific to systems that support language use, can affect comprehension when the sentence structure is complex even though the basic grammar is, to the best of our knowledge, intact. It can also lead to severe difficulties in the comprehension of printed text because short-term memory function is hobbled by slow and inaccurate word recognition.

We have identified three problems of the poor reader: (a) difficulty in becoming aware of sublexical structure for the purpose of developing word-recognition strategies, (b) unreliable access to the phonological representations in the internal lexicon for naming objects and for performing metalinguistic tasks involving phonological properties of words, and (c) the deficient use of phonetic properties as a basis for the short-term working memory operations that underlie the processing of connected language in any form. We cannot fail to notice that all of these are deficits in lower level abilities. It is an important task for future research to determine how these abilities, each of which involves the phonological component of the language apparatus, are related in development and pathology.

There is now much evidence that metalinguistic abilities in the phonological domain can be taught at all ages with significant success. Moreover, there is increasing evidence that such phonological instruction has beneficial effects on proficiency in reading words. We know relatively little about the role of instruction in developing and maintaining or expanding the phonetic short-term memory system required for sentence comprehension. But whether or not phonetic memory function can be improved by instruction, we know that pressure on short-term memory is reduced as reading strategies become more efficient. Thus, fostering phonological development in the beginning reader may serve to improve not only the reading of words, but also the comprehension of sentences. Various ways to promote phonological development have been outlined elsewhere (Bradley & Bryant, 1983; Liberman et al., 1980b; Olofsson & Lundberg, 1983). However, the creative teacher who understands the basic problems the child faces in learning to read and write will have no trouble devising other, equally appropriate, techniques.

ACKNOWLEDGMENT

This research was supported, in part, by grant HD-01994 to Haskins Laboratories from the National Institute of Child Health and Human Development. We are grateful to Alvin M. Liberman for his criticisms of earlier drafts of this paper. We also thank Stephen Crain for his comments on the manuscript. This paper is adapted from "Phonology and the Problems of Learning to Read and Write" by I. Y. Liberman & D. Shankweiler, 1985, *Remedial and Special Education, 6,* 8–17.

REFERENCES

Alegria, J., Pignot, E., & Morais, J. (1982). Phonetic analysis of speech and memory codes in beginning readers. *Memory & Cognition, 10,* 451–456.

Blachman, B. (1983). Are we assessing the linguistic factors critical in early reading? *Annals of Dyslexia, 33,* 91–109.

Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read—a causal connection. *Nature, 301,* 419–421.

Brady, S., Shankweiler, D., & Mann, V. (1983). Speech perception and memory coding in relation to reading ability. *Journal of Experimental Child Psychology, 35,* 345–367.

Byrne, B. (1981). Deficient syntactic control in poor readers: Is a weak phonetic memory code responsible? *Applied Psycholinguistics, 2,* 201–212.

Byrne, B., & Ledez, J. (1983). Phonological awareness in reading-disabled adults. *Australian Journal of Psychology, 35,* 185–197.

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language, 3,* 572–582.

Conrad, R. (1964). Acoustic confusions in immediate memory. *British Journal of Psychology, 55,* 75–84.

Conrad, R. (1972). Speech and reading. In J. Kavanagh & I. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading* (pp. 205–240). Cambridge, MA: MIT Press.

Content, A., Morais, J., Alegria, J., & Bertelson, P. (1982). Accelerating the development of phonetic segmentation skills in kindergarteners. *Cahiers de Psychologie Cognitive, 2,* 259–269.

Crain, S., & Shankweiler, D. (in press). Syntactic complexity and reading acquisition. In A. Davison, G. Green, & G. Herman (Eds.), *Critical approaches to readability: Theoretical bases of linguistic complexity.* Hillsdale, NJ: Erlbaum.

Crowder, R. G. (1978). Language and memory. In J. F. Kavanagh & W. Strange (Eds.), *Speech in the laboratory, school, and clinic* (pp. 331–375). Cambridge, MA: MIT Press.

Denckla, M. B., & Rudel, R. G. (1976). Naming of object-drawings by dyslexic and other learning disabled children. *Brain and Language, 3,* 1–15.

Fox, B., & Routh, D. K. (1980). Phonetic analysis and severe reading disability in children. *Journal of Psycholinguistic Research, 9,* 115–119.

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition, 6,* 291–325.

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology, 14,* 178–210.

Goldstein, D. M. (1976). Cognitive-linguistic functioning and learning to read in preschoolers. *Journal of Educational Psychology, 68*, 680–688.

Helfgott, J. (1976). Phoneme segmentation and blending skills of kindergarten children: Implications for beginning reading acquisition. *Contemporary Educational Psychology, 1*, 157–169.

Jansky, J., & deHirsch, K. (1973). *Preventing reading failure*. New York: Harper and Row.

Kaplan, E., Goodglass, H., & Weintraub, S. (1976). *Boston naming test*. Boston: Boston University School of Medicine.

Katz, R. B. (1986). Phonological deficiencies in children with reading disability: Evidence from an object-naming task. *Cognition, 22*, 225–257.

Katz, R. B., Shankweiler, D., & Liberman, I. Y. (1981). Memory for item order and phonetic recoding in the beginning reader. *Journal of Experimental Child Psychology, 32*, 474–484.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review, 74*, 431–461.

Liberman, A. M., & Mattingly, I. G. (1985). The motor theory of speech perception reconsidered. *Cognition, 21*, 1–37.

Liberman, A. M., Mattingly, I. G., & Turvey, M. (1972). Language codes and memory codes. In A. W. Melton & E. Martin (Eds.), *Coding processes and human memory* (pp. 307–334). Washington, DC: Winston and Sons.

Liberman, A. M., & Studdert-Kennedy, M. (1978). Phonetic perception. In R. Held, H. W. Leibowitz, & H.-L. Teuber (Eds.), *Handbook of sensory physiology, Vol. VIII: Perception* (pp. 143–178). New York: Springer-Verlag.

Liberman, I. Y. (1971). Basic research in speech and lateralization of language: Some implications for reading disability. *Bulletin of the Orton Society, 21*, 71–87.

Liberman, I. Y. (1973). Segmentation of the spoken word and reading acquisition. *Bulletin of the Orton Society, 23*, 65–77.

Liberman, I. Y. (1983). A language-oriented view of reading and its disabilities. In H. Myklebust (Ed.), *Progress in learning disabilities* (Vol. 5, pp. 81–101). New York: Grune & Stratton.

Liberman, I. Y., Liberman, A. M., Mattingly, I. G., & Shankweiler, D. (1980a). Orthography and the beginning reader. In J. F. Kavanagh & R. L. Venezky (Eds.), *Orthography, reading, and dyslexia* (pp. 137–153). Austin, TX: Pro-Ed.

Liberman, I. Y., Mann, V. A., Shankweiler, D., & Werfelman, M. (1982). Children's memory for recurring linguistic and non-linguistic material in relation to reading ability. *Cortex, 18*, 367–375.

Liberman, I. Y., Rubin, H., Duques, S. L., & Carlisle, J. (1985). Linguistic skills and spelling proficiency in kindergarteners and adult poor spellers. In D. B. Gray & J. F. Kavanagh (Eds.), *Biobehavioral Measures of Dyslexia*. Parkton, MD: York Press.

Liberman, I. Y., & Shankweiler, D. (1979). Speech, the alphabet and teaching to read. In L. B. Resnik & P. A. Weaver (Eds.), *Theory and practice of early reading* (Vol. 2, pp. 109–134). Hillsdale, NJ: Erlbaum.

Liberman, I. Y., Shankweiler, D., Camp, L., Blachman, B., & Werfelman, M. (1980b). Steps toward literacy. In P. Levinson & C. Sloan (Eds.), *Auditory processing and language: Clinical and research perspectives* (pp. 189–215). Orlando, FL: Grune & Stratton.

Liberman, I. Y., Shankweiler, D., Fischer, F. W., & Carter, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology, 18*, 201–212.

Liberman, I. Y., Shankweiler, D., Liberman, A. M., Fowler, C., & Fischer, F. W. (1977). Phonetic segmentation and recoding in the beginning reader. In A. S. Reber & D. L. Scarborough (Eds.), *Toward a psychology of reading: The proceedings of the CUNY Conferences* (pp. 207–225). Hillsdale, NJ: Erlbaum.

Treiman, R., & Baron, J. (1981). Segmental analysis ability: Development and relation to reading ability. In G. E. MacKinnon & T. G. Waller (Eds.), *Reading research: Advances in theory and practice* (Vol. 3, pp. 159–197). Orlando, FL: Academic Press.

Vellutino, F. R. (1979). *Dyslexia: Theory and research*. Cambridge, MA: MIT Press.

Vellutino, F. R. (1985). Phonological coding: Phoneme segmentation and code acquisition in poor and normal readers. In D. B. Gray & J. F. Kavanagh (Eds.), *Biobehavioral Measures of Dyslexia*. Parkton, MD: York Press.

Vogel, S. A. (1975). *Syntactic abilities in normal and dyslexic children*. Baltimore, MD: University Park Press.

Wolf, M. (1981). The word-retrieval process and reading in children and aphasics. In K. Nelson (Ed.), *Children's language* (Vol. 3). New York: Gardner.

Wolford, G., & Fowler, C. A. (1983). Perception and use of information by good and poor readers. In T. Tighe & B. Shepp (Eds.), *Perception, cognition, and development: Interactional analyses* (pp. 267–292). Hillsdale, NJ: Erlbaum.

Zifcak, M. (1981). Phonological awareness and reading acquisition. *Contemporary Educational Psychology*, 6, 117–126.

Lundberg, I., Olofsson, A., & Wall, S. (1980). Reading and spelling skills in the first school years, predicted from phonemic awareness skills in kindergarten. *Scandinavian Journal of Psychology, 21,* 159–173.

Mann, V. A., & Liberman, I. Y. (1984). Phonological awareness and verbal short-term memory: Can they presage early reading problems? *Journal of Learning Disabilities, 17,* 592–599.

Mann, V. A., Liberman, I. Y., & Shankweiler, D. (1980). Children's memory for sentences and word strings in relation to reading ability. *Memory & Cognition, 8,* 329–335.

Mann, V. A., Shankweiler, D., & Smith, S. (1984). The association between comprehension of spoken sentences and early reading ability: The role of phonetic representation. *Journal of Child Language, 11,* 627–643.

deManrique, A. M. B., & Gramigna, S. (1984). La segmentacion fonologica y silabica en ninos de preescolar y primer grado. *Lectura y Vida, 5,* 4–13.

Marcel, A. (1980). Phonological awareness and phonological representation: Investigation of a specific spelling problem. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 373–403). London: Academic Press.

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.

Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phonemes arise spontaneously? *Cognition, 7,* 323–331.

Morais, J., Cluytens, M., & Alegria, J. (1984). Segmentation abilities of dyslexics and normal readers. *Perceptual and Motor Skills, 58,* 221–222.

Olofsson, A., & Lundberg, I. (1983). Can phonemic awareness be trained in kindergarten? *Scandinavian Journal of Psychology, 24,* 35–44.

Olson, R. K., Davidson, B. J., Kliegl, R., & Davies, S. E. (1984). Development of phonetic memory in disabled and normal readers. *Journal of Experimental Psychology, 37,* 187–206.

Perfetti, C. A., & Hogaboam, T. (1975). The relationship between single word decoding and reading comprehension skill. *Journal of Educational Psychology, 67,* 461–469.

Pratt, A. (1985). *The relationship of linguistic awareness to reading skill in children and adults.* Unpublished doctoral dissertation, University of Rhode Island.

Read, C. (1971). Pre-school children's knowledge of English phonology. *Harvard Educational Review, 41,* 1–34.

Read, C., Ahang, Y., Nie, H., & Ding, B. (1984). *The ability to manipulate speech sounds depends on knowing alphabetic spelling.* Paper presented at the International Congress of Psychology, Acapulco, Mexico.

Read, C., & Ruyter, L. (1985). Reading and spelling skills in adults of low literacy. *Remedial and Special Education, 6,* 43–52.

Rosner, J. (1975). *Helping children overcome learning difficulties.* New York: Walker.

Shankweiler, D., Liberman, I. Y., Mark, L. S., Fowler, C. A., & Fischer, F. W. (1979). The speech code and learning to read. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 531–545.

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.

Stanovich, K. E. (1982). Individual differences in the cognitive processes of reading: I. Word decoding. *Journal of Learning Disabilities, 15,* 449–512.

Tavakolian, S. L. (1981). The conjoined-clause analysis of relative clauses. In S. Tavakolian (Ed.), *Language acquisition and linguistic theory* (pp. 167–187). Cambridge, MA: MIT Press.