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## Phonetic Segmentation and Recoding in the Beginning Reader

Isabelle Y. Liberman<sup>1</sup>

Donald Shankweiler<sup>1</sup>

Alvin M. Liberman<sup>2</sup>

Carol Fowler

F. William Fischer

*University of Connecticut*

### 1 INTRODUCTION

The beginning reader—the child of six or thereabout—is an accomplished speaker—hearer of his language and has been for a year or more. Why, then, should he find it hard to read, as so many children do? Why does he not learn to read as naturally and inevitably as he learned to speak and listen? What other abilities, not required for mastery of speech, must he have if he is to cope with language in its written form?

If the beginning reader is to take greatest advantage of an alphabet and of the language processes he already has, he must convert print to speech or, more covertly, to the phonetic structure that in some neurological form must be presumed to underlie and control overt speech articulation. In the first part of the chapter we will say why it might be hard to make the conversion properly—that is, so as to gain all the advantages that an alphabetic system offers. But the conversion from print to speech, whether properly made or not, may be important to the child also in reducing that which is read to a meaningful message. That is so because of a basic characteristic of language: the meaning of

<sup>1</sup> Isabelle Y. Liberman and Donald Shankweiler are also associated with Haskins Laboratories, New Haven, Connecticut.

<sup>2</sup> Alvin M. Liberman is also associated with Haskins Laboratories and Yale University.

the longer segments (for example, sentences) transcends the meaning of the shorter segments (for example, words) out of which they are formed. From that it follows that the shorter segments must be held in some short-term store until the meaning of the longer segments has been computed. In the second part of the chapter we will consider the possibility that a phonetic representation may be particularly suited to that requirement.

In referring to the conversion of print to speech, which is what much of this presentation is about, we will not be especially concerned to make a distinction between overt speech and the covert neurological processes (isomorphic, presumably, with the phonetic representation) that govern its production and perception. We should only note that the beginning reader often converts to overt speech and the skilled reader to some more covert form; conversion to the covert form does not, of course, limit the reader to the relatively slow rates at which he can overtly articulate. Nor will we be concerned with the distinction between the phonetic and the more abstract phonological representations. Like many alphabetically written languages, English makes contact, not at the phonetic level, but at some more abstract remove, closer surely to the level of systematic phonologic structure (Chomsky, 1970; Klima, 1972; see also Gleitman & Rozin, this volume) or, in the older terminology, to the phonemic and morphophonemic levels. That is an important consideration for students of the reading process, but it happens not to be especially relevant to our purposes here. For convenience, then, we will speak of phonemes, phonetic segments, and phonetic structure without meaning to imply any differences in the abstractness of the units being referred to.

## 2 USING THE ALPHABET TO FULL ADVANTAGE

### 2.1 The Need to Segment Phonetically

For the moment we will concern ourselves only with the first problem: what a child needs in order to read an alphabetic language properly. In that connection, let us look at the strategies the beginning reader might use to recover a phonetic representation of the written word. In the early stages of learning to read, there are at least two possibilities: the child might work analytically, by first relating the orthographic components of the written word to the segmental structure of the spoken word, or he might do it holistically, as in the whole-word method, by simply associating the overall shape of the written word with the appropriate spoken word.<sup>3</sup> In the whole-word strategy, the child not only does not analyze

<sup>3</sup>We do not contend that the use of either strategy is necessarily tied to a particular method of instruction. For example, a child may have arrived by induction at the mapping principles required to use the analytic strategy without having been taught the rules as such. Moreover, in later stages of reading, these strategies are not mutually exclusive. There are undoubtedly many words, and even whole phrases, that are recognized as gestalts by the expert, mature reader, who is able to switch to a more analytic strategy as the circumstances require.

words into their phonetic components, but need not necessarily even be aware that such an analysis can be made. There are, however, several problems with this strategy. An obvious one, of course, is that it is self-limiting; it does not permit the child to read words not previously encountered in print. In the whole-word strategy, each new word must be learned as a unit, as if it were an ideographic character, before it can be read. Only if the child is able to use the more analytic strategy can he realize the important advantages of an alphabetically written language. Given a word that is already in his lexicon, the child can read it without specific instruction although he has never before seen it in print; or given a new word which he has never before heard or seen, the child can closely approximate its spoken form and hold that until its meaning can be inferred from the context or discovered later by his asking someone about it. In connection with the latter advantage, one might ask why the child cannot similarly hold the word in visual form. Perhaps he can. We know, however, that the spoken form can be retained quite easily and, indeed, that it can be readily called up. As to what can be done with a purely visual representation, we are not so sure. At all events, and as we will say at greater length later, spoken language, or its underlying and covert phonetic representation, seems particularly suited for storage of the short-term variety.

What special ability does the child need, then, if he is to employ the analytic strategy and thus take full advantage of the alphabetic way our language is written? In our view, it is the ability to become more explicitly aware of the fact that speech consists of phonetic segments. Consider, for example, what is involved in reading a simple word like *bag*. Let us assume that the child can (visually) identify the three letters of the word. Let us assume further that he knows the individual letter-to-sound correspondences—that the sound of *b* is /b $\Delta$ /, that *a* is / $\alpha$ /, and that *g* is /g $\Delta$ / . But if that is all he knows, he will sound out the word as *buhaguh*, a nonsense trisyllable containing five phonetic segments, and not as *bag*, a meaningful monosyllable which has only three phonetic segments. It is patent that if he is to map the printed three-letter word *bag* onto the spoken word *bag* which is already in his lexicon, he must know that the spoken syllable also has three segments.

## 2.2 The Difficulties of Making Phonetic Segmentation Explicit

Given that the child must be able to make explicit the phonetic segmentation of the word, is there any reason to believe that he might encounter difficulties? There is, indeed, and it comes directly from research on acoustic cues for speech perception. The relevant finding is that there is most commonly no acoustic criterion by which the phonetic segmentation of a given word is dependably marked (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Phoneme boundaries are not marked acoustically because the segments of the phonetic message are often coarticulated with the result, for example, that a consonant segment will, at the acoustic level, be encoded into—that is, merged with—the

vowel. The word *bag*, for example, has three phonetic segments but only one acoustic segment. Thus, there is no acoustic criterion by which one can segment the word into its three constituent phonemes. Analyzing an utterance into syllables, on the other hand, may present a different and easier problem. We should expect that to be so because every syllable contains a vocalic nucleus and thus will have, in most cases, a distinctive peak of acoustic energy. These energy peaks provide audible cues that correspond approximately to the syllable centers (Fletcher, 1929). Although such auditory cues could not in themselves help a listener to define exact syllable boundaries, they ought to make it relatively easy for him to discover how many syllables there are and, in that sense, to do explicit syllable segmentation.

We should remark here that the encoding or merging of phones at the level of sound not only complicates the task of explicit segmentation but also makes it impossible to read by sounding out the letters one by one. In the example of *bag* offered earlier, sounding out produces *buhaguh*. Hence, the analytic strategy we have been talking about does not—indeed, cannot—mean reading letter by letter. To recover the spoken form the reader must, before making the conversion to speech, take into account all the letters that represent the several phonetic segments that are to be encoded. In the example of *bag*, the coding unit is obviously the syllable. But coding influences sometimes extend across syllables, and in the case of prosody such influences may cover quite long stretches. We should think, therefore, that the number of letters that must be apprehended before an attempt can be made to recover the spoken form may sometimes be quite large. In fact, we do not now know exactly how large these coding units are, only that they almost always exceed one letter in length. To identify such units is, in our view, a research undertaking of great importance and correspondingly great difficulty.

We should also remark here that the child who finds it difficult to make explicit the phonetic segmentation of his speech need not have any problems at all in the regular course of speaking and listening. Children generally distinguish (or identify) words like *bad* or *bag* which differ in only one phonetic segment. Indeed, there is evidence now that infants at one month of age discriminate *ba* from *pa* (and *da* from *ta*) and, moreover, that they make this discrimination categorically, just as adults do (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). The child has no difficulty in speaking and listening to speech because there the segmentation of the largely continuous acoustic signal is done for him automatically by operations of which he is not conscious. In order to speak and listen, therefore, he need have no more conscious awareness of phonetic structure than he has of syntactic structure. In that connection, we all know that the child can speak grammatical sentences without being able to verbalize their structure. Similarly, he can readily distinguish *bad* from *bag* without being able to analyze the underlying phonetic structure—that is, without an explicit understanding of the fact that each of these utterances consists of three segments and



that the difference lies wholly in the third. But reading, unlike speech, does require a more explicit analysis if the advantages of an alphabet are to be realized.

That explicit phonetic analysis might be difficult is suggested also by the history of writing (Gelb, 1963).<sup>4</sup> In the very earliest systems, the segment that the orthography represented was the word. Present-day approximations to that kind of writing are to be found in Chinese characters and in the very similar kanji that the Japanese use. Writing with meaningless units is a more recent development, the segment size represented in all the earliest forms being the syllable. An alphabet, representing the shortest meaningless segments (phones or phonemes), developed still later and apparently out of a syllabary. Moreover, all the other systems, whether comprising meaningful or meaningless segments of whatever size, seem to have appeared independently in various places and at various times, but all the alphabets were derived from a single source. It seems reasonable to suppose that the historical development of writing systems—from word, to syllable, to phoneme—might reflect the ease or difficulty of explicitly carrying out the particular type of segmentation that each of these orthographies requires. More to the point of our present concerns, one would suppose that for the child there might be the same order of difficulty and, correspondingly, the same order of appearance in development.

### 2.3 Development of the Ability to Analyze Speech into Phonemes and Syllables

There is thus reason to suppose that phonetic segmentation might be a difficult task, more difficult than syllabic segmentation, and that the ability to do it might, therefore, develop later. To test that supposition directly, we have recently resorted to an experiment. The point was to determine how well children in nursery school, kindergarten, and first grade (4-, 5-, and 6-year-olds) can identify the number of phonetic segments in spoken utterances and how this compares with their ability to deal similarly with syllables (Liberman, Shankweiler, Fischer, & Carter, 1974). The procedure was in the form of a game which required of the child that he indicate, by tapping a wooden dowel on the table, the number (from one to three) of segments (phonemes in the case of one group, syllables in the other) in a list of test words. In order to teach the child what was expected of him, the test list was preceded by a series of training trials in which the experimenter demonstrated how the child was to respond. The test proper consisted of 42 randomly assorted individual items of one, two, or three segments, presented without prior demonstration and corrected, as needed, immediately after the child's response. Each of the 42 items occurred once in

<sup>4</sup>This point is discussed at greater length in Liberman, Shankweiler, Fischer, and Carter (1974), and in Gleitman and Rozin, this volume.

the test list. Testing was continued through all 42 items or until the child reached a criterion of tapping six consecutive trials correctly without demonstration. The children of each grade level were divided into two experimental groups, the one performing phoneme segmentation and the other, syllable segmentation. Instructions given the two groups were identical, except that the training and test items required phoneme segmentation in one group and syllable segmentation in the other.

The results showed in more than one way that the test words were more readily segmented into syllables than into phonemes. At all grade levels, the number of children who were able to reach criterion was markedly greater in the group required to segment by syllable than in the group required to segment by phoneme. At age four, none of the children could segment by phoneme, whereas nearly half (46%) could segment by syllable. Ability to carry out phoneme segmentation successfully did not appear until age five, and then it was demonstrated by only 17% of the children. In contrast, almost half (48%) of the children at that age again could segment syllabically. Even at age six, only 70% succeeded in phoneme segmentation, while 90% were successful in the syllable task.

The proportions of children at each age who reached criterion level in the minimum number of trials is another measure of the contrast in difficulty of the two tasks. For the children who worked at the syllable task, the percentage reaching criterion in the minimum time increased steadily over the three age levels. It was 7% at age four, 16% at age five, and 50% at age six. By contrast, we find in the phoneme group that no child at any grade level attained the criterion in the minimum time.

The data were also analyzed in terms of mean errors. In Fig. 1, mean errors to passing or failing the criterion of six consecutive correct trials without demonstration are plotted by task and grade. Errors on both the syllable and phoneme tasks decreased monotonically at successive grade levels, but the greater difficulty of phoneme segmentation at every level was again clearly demonstrated.

#### 2.4 Segmentation and Reading

The difficulty of phonetic segmentation has been remarked by a number of investigators besides ourselves (Calfee, Chapman, & Venezky, 1972; Elkonin, 1973; Gibson & Levin, 1975; Gleitman & Rozin, 1973; Rosner & Simon, 1970; Savin, 1972). Their observations, together with ours described in the experiment above, also imply a connection between phonetic segmentation ability and early reading acquisition. This relationship is suggested in our experiment by the increase in the number of children passing the phoneme-counting task, from only 17% at age five to 70% at age six. Unfortunately, the nature of the connection is in doubt. On the one hand, the increase in ability to segment phonetically might result from the reading instruction that begins between five

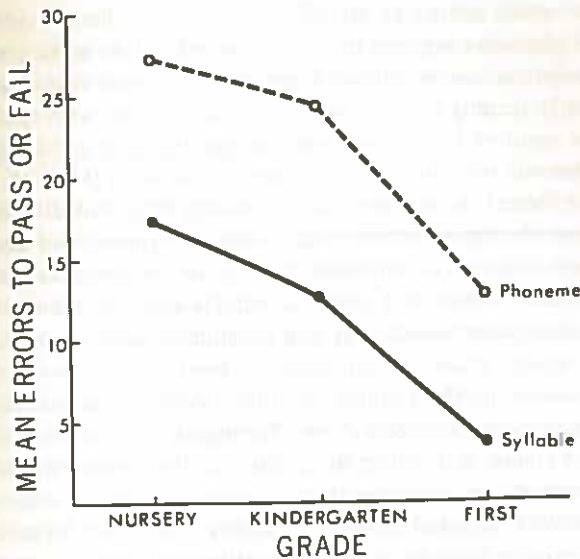


FIG. 1. Mean number of errors to passing or failing a criterion of six consecutive trials without demonstration in phoneme and syllable segmentation.

and six. Or, alternatively, it might be a manifestation of some kind of intellectual maturation. The latter possibility might be tested by a developmental study of segmentation skills in a language community such as the Chinese, where the orthographic unit is the word and where reading instruction therefore does not demand the kind of phonetic analysis needed in an alphabetic system.<sup>5</sup>

In any event, since explicit phoneme segmentation is harder for the young child and develops later than syllable segmentation, one would expect that syllable-based writing systems would be easier to learn to read than those based on an alphabet. We may thus have an explanation for the assertion (Makita, 1968) that the Japanese kana, roughly a syllabary, is readily mastered by first-grade children. One might expect, furthermore, that an orthography which represents each word with a different character (as is the case in Chinese logographs and in the closely related Japanese kanji) would obviate the difficulties in initial learning that arise in mastering an alphabetic system. The relative ease with which reading-disabled children learn kanjilike representations of language, while being unable to break the alphabetic code (Rozin, Poritsky, & Sotsky, 1971), may be cited here as evidence of the special burden imposed by an alphabetic script.

<sup>5</sup>Unfortunately, a pure test will be hard to make. Children in the People's Republic of China are now being taught to read alphabetically before beginning their study of logographic characters.

However, we need not go so far afield to collect indirect evidence that the difficulties of phoneme segmentation may be related to early reading acquisition. Such a relation can be inferred from the observation that children who are resistant to early reading instruction have problems even with spoken language when they are required to perform tasks demanding some rather explicit understanding of phonetic structure. Such children are reported (Monroe, 1932; Savin, 1972) to be deficient in rhyming, in recognizing that two different monosyllables may share the same first (or last) phoneme segment, and also in speaking Pig Latin, which demands a deliberate shift of the initial consonant segment of the word to initial position in a nonsense syllable added to the end of the word.

We, too, have explored directly, if in a preliminary way, the relation between an ability to segment phonemes and reading. For that purpose we measured the reading achievement of the children who had taken part in our experiment on phonetic segmentation, described above. Testing at the beginning of the second school year, we found that half of the children in the lowest third of the class in reading achievement (as measured by the word-recognition task of the Wide Range Achievement Test; Jastak, Bijou, & Jaskak, 1965) had failed the phoneme segmentation task the previous June; on the other hand, there were no failures in phoneme segmentation among the children who scored in the top third in reading ability (Liberman, 1973).

Data from the analysis of children's reading errors also may be cited as additional evidence for the view that failure to perform explicit phoneme segmentation may be a serious roadblock to reading acquisition. If a chief source of reading difficulty is that the child cannot make explicit the phonetic structure of the language, he might be expected to show success with the initial letter—which requires no further analysis of the syllable—and relatively poor performance beyond that point. If he knows some letter-to-sound correspondences, and that he must scan in a left-to-right direction, he might simply search his lexicon for a word, any word, beginning with a phoneme that matches the initial letter. Thus, presented with the word *bag*, he might give the response *butterfly*. Such a response could not occur if the child were searching his lexicon for a word that has three sound segments corresponding to the letter segments in the printed word. If, however, the child is unaware that words in his lexicon have a phonetic structure, or if he has difficulty in determining what that structure is, then he will not be able to map the letters to the segments in these words. On these grounds, we would expect that in reading words such a child would make more errors on final consonants than on initial consonants. We have observed just this error pattern in a number of beginning and disabled readers, ages 7 to 11 (Shankweiler & Liberman, 1972; Liberman, 1973; Fowler, Liberman, & Shankweiler, in press). Similar findings have been reported by other investigators (Daniels & Diack, 1956; Weber, 1970) who examined error patterns in reading connected text. It is worth noting that the initial-final error pattern in reading is contrary to what would be expected in terms of left-to-right sequential proba-



bilities (Miller, Bruner, & Postman, 1954). If the child at the early stages of beginning to read were using the constraints built into the language, he would make fewer errors at the end than at the beginning of words, not more.

## 2.5 The Contribution of Orthographic Complexity

In stressing the difficulty of phonemic segmentation, we do not intend to imply that no other problems are involved in reading an alphabetic language. For example, we realize that the mapping in English between spelling and language is sometimes complex and irregular.<sup>6</sup> Although that undoubtedly contributes to the difficulties of reading acquisition, we do not believe that the complexity of the orthography is the principal cause. Indeed, we know that it cannot be the only cause since many children continue to have problems even when the words are carefully chosen to include only those which map the sound in a consistent way and are part of the child's active vocabulary (Savin, 1972). Moreover, reading problems are known to occur in countries in which the writing system maps the language more directly than in English (Downing, 1973).

In any event, the major irregularities of English spelling which confront the young child in the simple words he must read have to do mainly with the vowels (Dewey, 1970; Heilman, 1964; Monroe, 1932). Although we believe it to be of interest to examine the relation of orthographic complexity of the vowels to the problems of reading acquisition, and we are doing so (Fowler et al., in press), we suspect that getting the vowel exactly right may not be of critical importance in reading (though, of course, it is in spelling). If in the conversion to sound the child gets the phonetic structure correct except for errors in vowel color, he would not be too wide of the mark, and many such errors would be rather easily corrected by context or by information obtained at a later time.

## 3 THE PHONETIC REPRESENTATION, SHORT-TERM MEMORY, AND READING

### 3.1 Phonetic Recoding in Reading as a Way to Tap Primary Language Processes

Although beginning readers must surely recode phonetically if they are to cope with new words, we should wonder what they do with words (and phrases) they have read many times. Do they, in those cases, construct a phonetic representa-

<sup>6</sup>It is recognized that the "irregularities" of English spelling are more lawful than might appear, as in the spellings of "sign" and "signal" for example, which reflect morphological structure quite accurately (Chomsky, 1970). However, it must be said that this lawfulness can be appreciated only by the skilled reader and probably does not aid the beginner.

tion using either of the two strategies we described earlier, or do they, as some believe (Bever & Bower, 1966), go directly from print to meaning?

One can think of at least two reasons why phonetic recoding might occur even with frequently read materials. A not very interesting reason is that, having adopted the phonetic strategy to gain advantages in the early stages of learning, the reader continues with the habit although it may have ceased to be functional or even have become, as some might think, a liability. There is a more interesting reason, however, and one we are inclined to take more seriously. It derives from the possibility that working from a phonetic base is natural and necessary if the reader (including even one who is highly practiced) is to take advantage of the primary language processes that are so deep in his experience and, indeed, in his biology. Consider, for example, that the normal processes for storing, indexing, and retrieving lexical entries may be carried out on a phonetic base. If so, it is hard to see why the reader should develop completely new processes suited for the visual system and less natural, presumably, for the linguistic purposes than the old ones. Or consider what we normally do in coping with syntax, an essential step in arriving at the meaning of a sentence. Although we do not know much about how we decode syntax, it is virtually certain that we are aided significantly by the prosody, which marks the syntactic boundaries. What, then, is the cost to our understanding of what we read if we do not recover the prosody, using for that purpose the marks of punctuation and such subtle cues as skillful writers may know how to provide (Bolinger, 1957)? We find it hard to imagine how the reader could construct the prosody except upon a phonetic base.

There are, of course, other natural language processes that the reader can best exploit by constructing a phonetic representation. Among them is short-term storage, and it is that process that we will be concerned with in the remainder of this chapter. As we had occasion to point out earlier, it is characteristic of language that the meaning of longer segments (e.g., sentences) transcends the meaning of the shorter segments (words) out of which they are formed. It follows, then, that the listener and reader must hold the shorter segments in some short-term store if the meaning of the longer segments is to be extracted from them. Given what we know about the characteristics of the phonetic representation, we might suppose that, as Liberman, Mattingly, and Turvey (1972) have suggested, it is uniquely suited to the short-term storage requirements of language. But apart from what we or they might suppose, there is relevant experimental evidence.

### 3.2 Phonetic Representation of Visually Presented Material in Short-Term Memory

Some of the evidence comes from a class of experiments in which it has been found that when lists of letters or alphabetically written words are presented to be read and remembered, the confusions in short-term memory are phonetic

rather than optical (Baddeley, 1966, 1968, 1970; Conrad, 1963, 1964, 1972; Conrad, Freeman, & Hull, 1965; Conrad & Hull, 1964; Dornič, 1967; Hintzman, 1967; Kintsch & Buschke, 1969; Sperling, 1963; Thomasson, 1970 reported in Conrad, 1972). From that finding it has been inferred that the stimulus items had been stored in phonetic rather than visual form. Indeed, the tendency to recode visually presented items into phonetic form is so strong that, as Conrad (1972) has emphasized, adult subjects consistently do so recode even in experimental situations in which it is clearly disadvantageous to do so.

A similar kind of experiment (Erickson, Mattingly, & Turvey, 1973) suggests that exactly the same kind of phonetic recoding occurs even when the linguistic stimuli are not presented in a form (alphabetic) that represents the phonetic structure. For the purposes of that experiment the investigators used lists of kanji characters, which are essentially logographic, and Japanese subjects who were readers of kanji. As in the experiments with alphabetically spelled words, there was evidence that the stimulus items had been stored in short-term memory in phonetic rather than visual (or semantic) form.

There is also evidence that even nonlinguistic stimuli may, under some circumstances, be recoded into phonetic form and so stored in short-term memory. That evidence comes from work by Conrad (1972) who found that in short-term recall of pictures of common objects, confusions by older children and adults were clearly based on the phonetic forms of the names of the objects, rather than on their visual or semantic characteristics.

Although none of the experiments cited here dealt with natural reading situations, they are nevertheless relevant to the assumption that even skilled readers might recode phonetically, and that in so doing they might gain an advantage in short-term memory. It remains to be determined whether and to what extent readers rely on phonetic recoding for the short-term memory requirements of normal reading. Less generally, it remains to be determined also whether good and poor readers are distinguished by greater or lesser tendencies toward phonetic recoding. In the next section we will describe our first attempt to gain evidence bearing on this question.

### 3.3 Phonetic Recoding in Good and Poor Beginning Readers: An Experiment

Given the short-term memory requirements of the reading task and evidence for the involvement of phonetic coding in short-term storage, we might expect to find that those beginning readers who are progressing well and those who are doing poorly will be further distinguished by the degree to which they rely on phonetic recoding. To our knowledge no one has investigated this possibility; consequently, we set out to do so. The experiments we have done are outlined in detail elsewhere (Shankweiler & Liberman, in press). For our purposes, we will report briefly on only one experiment.

We used a procedure similar to one devised by Conrad (1972) for adult subjects in which the subject's performance is compared on recall of phonetically confusable (rhyming) and nonconfusable (nonrhyming) letters. Our expectation was that phonetically similar items would maximize phonetic confusability and thus penalize recall in subjects who use the phonetic code in short-term memory. Sixteen strings of five upper-case letters were presented to the subjects by projector tachistoscope. Eight of the five-letter strings were composed of rhyming consonants (drawn from the set B C D G P T V Z) and eight were composed of nonrhyming consonants (drawn from the set H K L Q R S W Y). The two series of five-letter strings (confusable and nonconfusable) were randomly interleaved. An exposure time of 3 sec was adopted after preliminary studies had shown that even adult subjects require exposures in excess of 2 sec in order to report all five letters reliably. The test was given twice: first with immediate recall, then with delayed recall. In the first condition, recall was tested immediately after presentation by having subjects print as many letters as could be recalled in each letter string, in the order given. In order to make the task maximally sensitive to the recall strategy, we then imposed a 15-sec delay between tachistoscopic presentation and the response of writing down the string of letters. The children were requested to sit quietly during the delay interval; no intervening task was imposed. We have reason to believe that subjects used this period for rehearsal. Many children were observed mouthing the syllables silently; other tapped their feet rhythmically; some could hardly be restrained from repeating the letters aloud.

As can be seen in Table 1, the subjects included three groups of school children who differed in level of attainment in reading as estimated by the word-recognition subtest of the Wide Range Achievement Test (WRAT) (Jastak et al., 1965). All were nearing completion of the second grade at the time the tests were conducted. There was no overlap in WRAT scores among the three groups. The first group, designated as the superior readers, comprised 17 children who were reading well ahead of their grade placement, having scored a mean grade equivalent of 4.9 on the WRAT. The second group, whom we call

TABLE 1  
Estimated Mean Reading Grade,<sup>a</sup> Mean Age, and IQ<sup>b</sup> for  
Second-Grade School Children Grouped According to  
Reading Attainment

Group	<i>n</i>	Age	IQ	Reading grade
Superior	17	8.0	113.9	4.9
Marginal	16	8.1	101.7	2.5
Poor	13	8.2	111.6	2.0

<sup>a</sup>Reading-grade equivalent score on reading subtest of Wide Range Achievement Test.

<sup>b</sup>Peabody Picture Vocabulary Test.



marginal readers, included 16 children who averaged slightly less than one-half year of lag in reading achievement (grade 2.5). The third group, 13 children in number, whom we call poor readers, obtained a mean WRAT equivalent of 2.0, indicating nearly a full year of retardation in reading. The three groups did not differ significantly in mean age. Their intelligence level, as measured by the Peabody Picture Vocabulary Test (Dunn, 1965), was closely matched in the two extreme groups, the superior and poor readers. The difference in IQ level in the marginal group is apparently of no serious consequence since, as will be seen below, the performances of the marginal and poor groups on the experimental tasks were not appreciably different from each other.

The responses were scored in two ways, with and without regard for serial position. In the first procedure, only those items listed in the correct serial position were counted correct. Thus, credit was given for incomplete strings only if the positions of the omitted items were indicated by blank spaces. The second procedure credited any items which occurred in the stimulus set regardless of the order in which they were written down. An analysis of variance was performed on each set of scores. The pattern of results was remarkably similar for data derived from each method of scoring. We display here the results of only the scoring procedure that takes account of serial position.

In Fig. 2, which displays the data in terms of mean errors summed over all serial positions in the letter strings, the upper plot gives the results for superior readers, while the middle and lower plots show the results for the marginal and poor readers, respectively. We see at once that the main differences are between the superior readers and the other two groups. It was found, in fact, that the marginal and poor readers did not differ significantly in their overall performance. For this reason, we need not consider them separately here and will therefore refer to them collectively instead, as the "inferior" readers.

It is immediately apparent that the superior group tends, overall, to make fewer errors in recall than the inferior readers. More notable, however, are the differences in the effects of phonetic similarity on the recall performance of the two reading groups. First, it is seen that, although phonetic similarity caused some deterioration in immediate recall for all the children, the effect was much greater for the superior group than for the inferior readers. Second, the differential effect of phonetic similarity is even more marked in the delay condition. For the superior group, the interposition of a delay interval steeply increased errors of recall of the phonetically confusable strings but produced no effect on the recall of nonconfusable strings. We may suppose that in both groups the phonetic similarity of the confusable strings caused interference with rehearsal during the delay interval. For the superior readers the interference effect is large, for the inferior readers it is small. In the latter group, there was no interaction of the effects of confusability with delay. Recall of both confusable and non-confusable strings deteriorated with delay by nearly equal amounts. This tells us that, for whatever reason, the inferior readers have a less efficient recall strategy

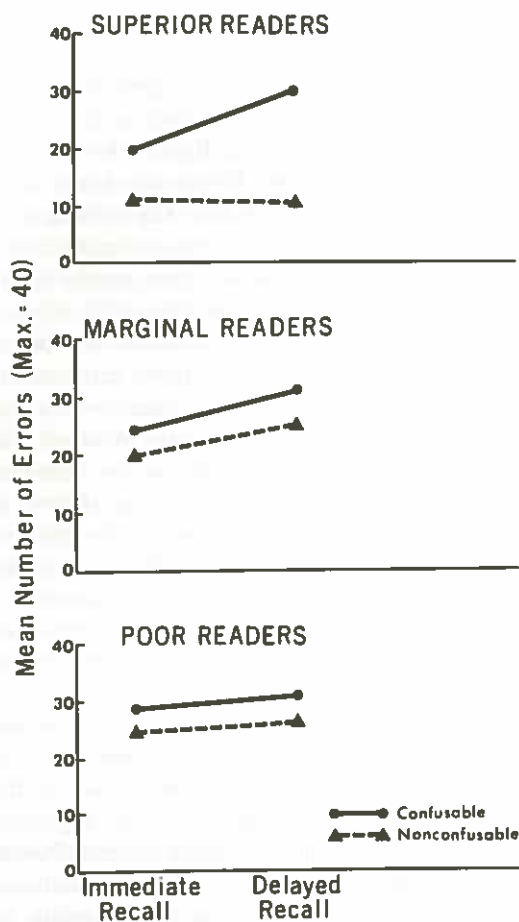


FIG. 2. Mean recall errors summed over serial position.

than the superior readers. We would suggest that the better recall of the superior readers is due to their more efficient use of phonetic recoding, a strategy that ordinarily works to their advantage, but not in the special case of rhyming strings.

The differential effect of phonetic similarity on the superior readers is again apparent in Fig. 3, where the data are replotted as a function of serial position. An examination of the two graphs in the lower half of the figure shows that, after delay, the superior readers are sharply distinguished from the inferior groups in their better recall of nonconfusable strings but are nearly indistinguishable from the others in their recall of confusable strings. Taken together, the two lower graphs make manifest the much greater penal effect of phonetic confusability on the superior readers. The same differentially penal effect on this

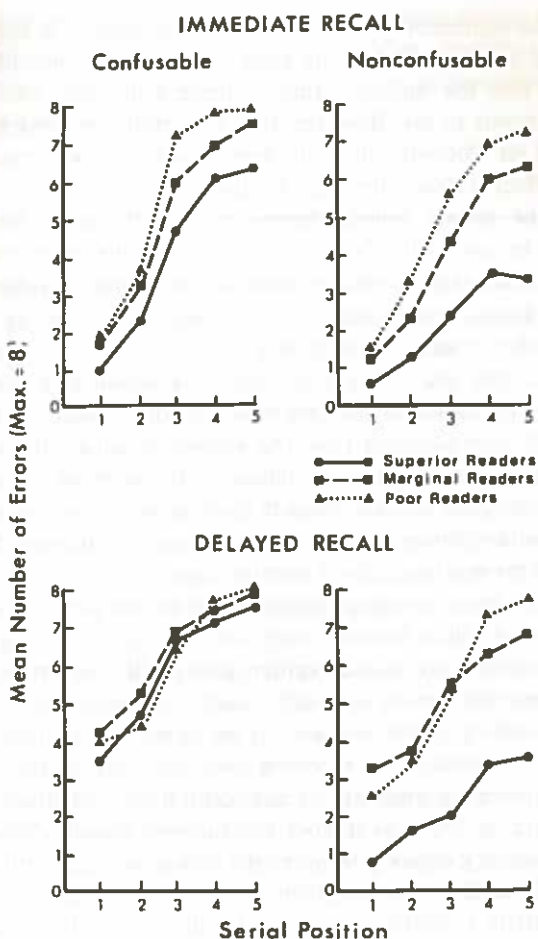


FIG. 3. Recall data replotted as a function of serial position.

group is found also in the case of immediate recall, as seen in the upper graphs of Fig. 3, but there the difference is less striking.<sup>7</sup>

In summary, then, the superior readers are strongly penalized by the phonetic

<sup>7</sup> An analysis of variance performed on the data showed all main effects to be significant at  $p < .001$  (reading group:  $F(2, 43) = 22.67$ ; delay:  $F(1, 43) = 29.77$ ; confusability:  $F(1, 43) = 73.00$ ). (The significance of the reading group factor is accounted for by the differences between the superior readers and the other two groups; the marginal and poor readers do not differ significantly from each other in recall.) The three-way interaction, reading group  $\times$  delay  $\times$  confusability, is statistically significant at  $p < .001$  (where  $F(2, 43) = 8.24$ ). Newman-Kuels post-hoc means tests reveal that for the superior readers, delay has a significantly greater effect on recall of confusable sequences than on recall of nonconfusable sequences. Among the marginal and poor readers, on the other hand, delay did not differentially affect performance on the two types of sequences.

similarity of the confusable strings of letters. The penalty is apparent in immediate recall and more marked in the delay condition. We should conclude from these findings that the superior group is using a phonetic code in short-term memory. This is not to say, however, that the inferior readers are not recoding phonetically at all. Phonetic similarity does impair their performance somewhat, although the effect is clearly less than for the superior group.

There may be several interpretations of this difference between the two reading groups in our study. One possibility is that the inferior readers rely less on phonetic recoding than does the superior group and use other codes concurrently (visual codes, for example), which are unaffected by phonetic confusability. Another possibility, suggested by R. G. Crowder (personal communication), is that they may simply rehearse at a slower rate than the superior readers, thereby giving the confusable items less opportunity to interfere. Whatever interpretation is accepted (and the answers must await further investigation), we would emphasize that the failure of the superior readers to maintain their advantage over the inferior group in short-term memory when the items are phonetically confusable cannot be accounted for by assuming that the groups differ only with respect to a general memory capacity.

An auditory analog of our experiment would be one way to clarify the nature of the difference in short-term memory between the two groups of readers.<sup>8</sup> Since phonetic coding, as we said earlier, presumably cannot be avoided when the linguistic material arrives auditorily, auditory presentation might force the inferior reader into a phonetic mode. If an important component of his difficulty is that he is deficient in recoding visual symbolic material into phonetic form, then the phonetic similarity of auditorily presented stimuli should affect him as much (or as little) as it does the superior readers. While quantitative differences in memory capacity between the two groups may still show up in the general level of recall on the auditory presentation, the interaction of reading group and phonetic confusability should be diminished. If, on the other hand, the poor reader tends generally in memory to rely, where possible, on non-phonetic codes or to rehearse phonetically but at a slower rate, the interaction should remain.

Obviously, many other refinements of the experimental task remain to be made. In particular, we should hope in the future to use tasks which resemble more closely what happens in actual reading. At the very least, we should like to

<sup>8</sup>Since the auditory experiment would, of course necessitate serial presentation, an additional visual condition employing serial presentation would be required to achieve comparability. In a pilot experiment, we have found virtually identical patterns of performance for the two types of presentation, the auditory and the visual. In both cases, phonetic similarity again hurts both groups of readers, especially in delayed recall, but the effect is again greater, although perhaps not clearly so, for the good readers than for the poor. It would seem from these results that the difference between the good and poor readers might be more general than we had assumed. That is, the difference might be related not so much to the visual or auditory source of the linguistic material but rather more generally to the way the two groups process linguistic information in short-term memory.



repeat the kind of experiment reported here using words instead of letters. Only after that, could we have a very high degree of confidence in the conclusion that seems to be suggested by the results of the present experiment—namely, that phonetic recoding is characteristic of skilled reading.

#### 4 SUMMARY

By converting print to speech the beginning reader gains two advantages: he can read words he has never seen before, and he can, as he reads, fully exploit the primary language processes of which he is already master. If he is to realize the first advantage, he must make the conversion analytically, not by whole words. That analytic conversion requires, in particular, an explicit awareness that speech is segmentable into units of phonemic size. Given what we know about the relation of speech sounds to phonetic structure, we can see why explicit segmentation might be hard to achieve. Recent research by us has shown that for young children such explicit segmentation is, in fact, difficult, more difficult in any case than segmentation into syllables, and that such difficulty may be related to success, or the lack of it, in the early stages of reading.

Among the primary language processes that the child can exploit by conversion to speech (either analytically or holistically) is the use of a phonetic representation to store smaller segments (words, for example) until the meaning of larger segments (phrases or sentences) can be extracted. Research on speech perception suggests that the phonetic representation may be uniquely suited to such storage. That the phonetic representation is, in fact, so suited is suggested by the outcome of many experiments on short-term memory. Now we have evidence from a similar experiment that, among second graders, good readers rely more on a phonetic representation than poor readers do.

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#### REFERENCES

- Baddeley, A. D. Short-term memory for word sequences as a function of acoustic, semantic and formal similarity. *Quarterly Journal of Experimental Psychology*, 1966, 18, 362-365.
- Baddeley, A. D. How does acoustic similarity influence short-term memory? *Quarterly Journal of Experimental Psychology*, 1968, 20, 249-264.

- Baddeley, A. D. Effects of acoustic and semantic similarity on short-term paired associate learning. *British Journal of Psychology*, 1970, 61, 335-343.
- Bever, T. G., & Bower, T. G. How to read without listening. *Project Literacy Reports*, 1966, No. 6, 13-25.
- Bolinger, D. L. Maneuvering for accent and position. *College Composition and Communication*, 1957, 8, 234-238.
- Calfee, R., Chapman, R., & Venezky, R. How a child needs to think to learn to read. In L. W. Gregg (Ed.), *Cognition in learning and memory*. New York: Wiley, 1972.
- Chomsky, C. Reading, writing and phonology. *Harvard Educational Review*, 1970, 40(2), 287-309.
- Conrad, R. Acoustic confusions and memory span for words. *Nature*, 1963, 197, 1029-1030.
- Conrad, R. Acoustic confusions in immediate memory. *British Journal of Psychology*, 1964, 55, 75-84.
- Conrad, R. Speech and reading. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading*. Cambridge, Massachusetts: MIT Press, 1972.
- Conrad, R., Freeman, P. R., & Hull, A. J. Acoustic factors versus language factors in short-term memory. *Psychonomic Science*, 1965, 3, 57-58.
- Conrad, R., & Hull, A. J. Input modality, acoustic confusion and memory span. *British Journal of Psychology*, 1964, 55, 429-432.
- Daniels, J. C., & Diack, H. *Progress in reading*. Nottingham: University of Nottingham Institute of Education, 1956.
- Dewey, G. *Relative frequency of English spellings*. New York: Teachers College Press, 1970.
- Dornič, S. Effect of a specific noise on visual and auditory memory span. *Scandinavian Journal of Psychology*, 1967, 8, 155-160.
- Downing, J. *Comparative reading*. New York: Macmillan, 1973.
- Dunn, L. M. *Peabody Picture Vocabulary Test*. Circle Pines, Minnesota: American Guidance Service, 1965.
- Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. Speech perception in infants. *Science*, 1971, 171, 303-306.
- Elkonin, D. B. U.S.S.R. In J. Downing (Ed.), *Comparative reading*. New York: Macmillan, 1973.
- Erickson, D., Mattingly, I. G., & Turvey, M. T. Phonetic activity in reading: An experiment with kanji. *Haskins Laboratories Status Report on Speech Research*, 1973, 33, 137-156.
- Fletcher, H. *Speech and hearing*. New York: Van Nostrand Co., 1929.
- Fowler, C. A., Liberman, I. Y., & Shankweiler, D. On interpreting the error pattern in beginning reading. *Language and Speech*, in press.
- Gelb, I. J. *A study of writing*. Chicago: University of Chicago Press, 1963.
- Gibson, E. J., & Levin, H. *The psychology of reading*. Cambridge: MIT Press, 1975.
- Gleitman, L. R., & Rozin, P. Teaching reading by use of a syllabary. *Reading Research Quarterly*, 1973, 8, 447-483.
- Hellman, A. W. *Phonics in proper perspective*. Columbus, Ohio: Charles E. Merrill, Inc., 1964.
- Hintzman, D. L. Articulatory coding in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, 1967, 6, 312-316.
- Jastak, J., Bijou, S. W., & Jastak, S. R. *Wide Range Achievement Test*. Wilmington, Delaware: Guidance Assoc., 1965.
- Kintsch, W., & Buschke, H. Homophones and synonyms in short-term memory. *Journal of Experimental Psychology*, 1969, 80, 403-407.
- Klima, E. How alphabets might reflect language. In J. F. Kavanagh & I. G. Mattingly (Eds.),

- Language by ear and by eye: The relationships between speech and reading.* Cambridge, Massachusetts: MIT Press, 1972.
- Lieberman, A. M., Cooper, F. S., Shankweiler, D., & Studdert-Kennedy, M. Perception of the speech code. *Psychological Review*, 1967, 74, 431-461.
- Lieberman, A. M., Mattingly, I. G., & Turvey, M. T. Language codes and memory codes. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, D.C.: Winston, 1972.
- Lieberman, I. Y. Segmentation of the spoken word and reading acquisition. *Bulletin of the Orton Society*, 1973, 23, 65-77.
- Lieberman, I. Y., Shankweiler, D., Fischer, F. W., & Carter, B. Reading and the awareness of linguistic segments. *Journal of Experimental Child Psychology*, 1974, 18, 201-212.
- Makita, K. Rarity of reading disability in Japanese children. *American Journal of Orthopsychiatry*, 1968, 38(4), 599-614.
- Miller, G. A., Bruner, J. S., & Postman, L. Familiarity of letter sequences and tachistoscopic identification. *Journal of General Psychology*, 1954, 50, 129-139.
- Monroe, M. *Children who cannot read*. Chicago: University of Chicago Press, 1932.
- Rosner, J., & Simon, D. P. *The auditory analysis test: An initial report*. Pittsburgh: University of Pittsburgh Learning Research and Development Center, 1970.
- Rozin, P., Poritsky, S., & Sotsky, R. American children with reading problems can easily learn to read English represented by Chinese characters. *Science*, 1971, 171, 1264-1267.
- Savin, H. B. What the child knows about speech when he starts to learn to read. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading*. Cambridge, Massachusetts: MIT Press, 1972.
- Shankweiler, D., & Liberman, I. Y. Misreading: A search for causes. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading*. Cambridge, Massachusetts: MIT Press, 1972.
- Shankweiler, D., & Liberman, I. Y. Exploring the relations between reading and speech. In R. Knights & D. J. Bakker (Eds.), *Neuropsychology of learning disorders: theoretical approaches*. Baltimore: University Park Press, in press.
- Sperling, G. A model for visual memory tasks. *Human Factors*, 1963, 5, 19-31.
- Thomasson, A. J. W. M. *On the representation of verbal items in short-term memory*. Nijmegen: Drukkerij, Schippers, 1970. Cited by R. Conrad (1972).
- Weber, R. A linguistic analysis of first-grade errors: A survey of the literature. *Reading Research Quarterly*, 1970, 4, 96-119.