Language by Ear and by Eye

The Relationships between Speech and Reading

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Misreading: A Search for Causes

Because speech is universal and reading is not, we may suppose that the latter is more difficult and less natural. Indeed, we know that a large part of the early education of the school child must be devoted to instruction in reading and that the instruction often fails, even in the most favorable circumstances. Judging from the long history of debate concerning the proper methods of teaching children to read [Mathews 1966], the problem has always been with us. Nor do we appear to have come closer to a solution: we are still a long way from understanding how children learn to read and what has gone wrong when they fail.

Since the child already speaks and understands his language at the time that reading instruction begins, the problem is to discover the major barriers in learning to perceive language by eye. It is clear that the first requirement for reading is that the child be able to segregate the letter segments and identify them with accuracy and speed. Some children undoubtedly do fail to learn to recognize letters and are unable to pass on to succeeding stages of learning to read; but, as we shall see, there are strong reasons for believing that the principal barriers for most children are not at the point of visual identification of letter shapes. There is no general agreement, however, about the succeeding stages of learning to read, their time course, and the nature of their special difficulties. In order to understand reading and compare it with speech, we need to look closely at the kinds of difficulties the child has when he starts to read, that is, his misreadings, and ask how these differ from errors in repeating speech perceived by ear. In this way, we may begin to grasp why the link between alphabet and speech is difficult.

In the extensive literature about reading since the 1890s there have been sporadic surges of interest in the examination of oral reading errors as a means of studying the process of reading acquisition. The history of this topic has been well summarized by Weber [1968], so need not be repeated here. We ourselves set out in many directions when we began our pursuit of errors and we regard our work as essentially exploratory. If we break new ground, it is not by our interest in error patterns nor even in many of our actual findings, but rather in the questions we are asking about them.

Much of the most recent research on reading errors has examined the child's oral reading of connected text [Goodman 1965, 1968; Schale 1966; Weber 1968; Christenson 1969; Biemiller 1970]. The major emphasis of these studies is therefore on levels beyond the word, though they are concerned to some extent with errors within words. None of these investigations asks what we believe to be a basic question: whether the major barrier to reading acquisition is indeed in reading connected text or whether it may be instead in dealing with words and their components.

We are, in addition, curious to know whether the difficulties in reading are to be found at a visual stage or at a subsequent linguistic stage of the process. This requires us to consider the special case of reversal errors, in which optical considerations are, on the face of it, primary. Our inquiry into linguistic aspects of reading errors then leads us to ask which constituents of words tend to be misread, and whether the same ones tend to be misheard. We examine errors with regard to the position of the constituent segments within the word and the linguistic status of the segments in an attempt to produce a coherent account of the possible causes of the error pattern in reading.

We think that all the questions we have outlined can be approached most profitably by studying children who are a little beyond the earliest stages of reading instruction. For this reason, we have avoided the first grade and focused, in most of our work, on children of the second and third grades of the elementary school. Though some of the children at this level are well on their way to becoming fluent in reading, a considerable proportion are still floundering and thus provide a sizeable body of errors for examination.

The Word as the Locus of Difficulty in Beginning Reading

One often encounters the claim that there are many children who can read individual words well yet do not seem able to comprehend connected text [Anderson and Dearborn 1952; Goodman 1968]. The existence of such children is taken to support the view that methods of instruction that stress spelling-to-sound correspondences and other aspects of decoding are insufficient and may even produce mechanical readers who are expert at decoding but fail to comprehend sentences. It may well be that such children do exist; if so, they merit careful study. Our experience suggests that the problem is rare, and that poor reading of text with little comprehension among beginning readers is usually a consequence of reading words poorly (i.e., with many errors and/or at a slow rate).

Table 1
Correlation of Performance of School Children on Reading Lists* and Paragraph Fluency as Measured by the Gray Oral Reading Test

Group	*n*	Grade	List 1	List 2
A	20	2.8	0.72	—†
B	18	3.0	0.77	—†
C	30	3.8	0.53	0.55
D	20	4.8	0.77	—†

* The correlation between the two lists was 0.73.
† No data available.

Table 2
Reading List 1: Containing Reversible Words, Reversible Letters, and Primer Sight Words

1. of	21. two	41. bat
2. boy	22. war	42. tug
3. now	23. bed	43. form
4. tap	24. felt	44. left
5. dog	25. big	45. bay
6. lap	26. not	46. how
7. tub	27. yam	47. dip
8. day	28. peg	48. no
9. for	29. was	49. pit
10. bad	30. tab	50. cap
11. out	31. won	51. god
12. pat	32. pot	52. top
13. ten	33. net	53. pal
14. gut	34. pin	54. may
15. cab	35. from	55. bet
16. pit	36. ton	56. raw
17. saw	37. but	57. pay
18. get	38. who	58. tar
19. rat	39. nip	59. dab
20. dig	40. on	60. tip

The purpose of our first experiment was to investigate whether the main source of difficulty in beginning reading is at the level of connected text or at the word level. We wished to know how well one can predict a child's degree of fluency in oral reading of paragraph material from his performance (accuracy and reaction time) on selected words presented in lists.

Table 1 shows correlations between a conventional measure of fluency in oral reading, the Gray Oral Reading Test, and oral reading performance on two words lists that we devised. The Gray test consists of paragraphs of graded difficulty that yield a composite score based on time and error from which may be determined the child's reading grade level. Both word lists, which are presented as Tables 2 and 3, contain monosyllabic words. Word List 1 (Table 2) was designed primarily to study the effects of optically based ambiguity on the error pattern in reading. It consists of a number of primer words and a number of reversible words from which other words may be formed by reading from right to left. List 2 (Table 3) contains words representing equal frequencies of many of the phonemes of English and was designed specifically to make the comparison between reading and perceiving speech by ear. Data from both lists were obtained from some subjects; others received one test but not the other. Error analysis of these lists was based on phonetic transcription of the responses, and the error counts take the phoneme as the unit.[1] Our selection of this method of treating that data is explained and the procedures are described in a later section.

In Table 1, then, we see the correlations between the Gray Test and one or both lists for four groups of school children, all of average or above-average intelligence: Group A, 20 second-grade boys (grade 2.8); Group B, 18 third-grade children who comprised the lower third of their school class in reading level (grade 3.0); Group C, an entire class

[1] Our method of analysis of errors does not make any hard and fast assumptions about the size of the perceptual unit in reading. Much research on the reading process has been concerned with this problem [Huey 1908; Woodworth 1938; Gough this volume]. Speculations have been based, for the most part, on studies of the fluent adult reader, but these studies have, nevertheless, greatly influenced theories of the acquisition of reading and views on how children should be taught (Fries 1962; Mathews 1966). In our view, this has had unfortunate consequences. Analysis of a well-practiced skill does not automatically reveal the stages of its acquisition, their order and special difficulties. It may be that the skilled reader does not (at all times) proceed letter by letter or even word by word, but at some stage in learning to read, the beginner probably must take account of each individual letter (Hochberg 1970).

Table 3
Reading List 2: Presenting Equal Opportunities for Error on Each Initial Consonant,* Medial Vowel, and Final Consonant*

help	teethe	than	jots	thus
pledge	stoops	dab	shoots	smelt
weave	bilk	choose	with	nudge
lips	hulk	thong	noose	welt
wreath	jog	puts	chin	chops
felt	shook	hood	rob	vim
zest	plume	fun	plot	vet
crisp	thatch	sting	book	zip
touch	zig	knelt	milk	plop
palp	teeth	please	vest	smug
stash	moot	this	give	foot
niece	foot's	that	then	chest
soothe	jeeps	dub	plug	should
ding	leave	vast	knob	clots
that's	van	clash	cook	rasp
mesh	cheese	soot	love	shops
deep	vets	sheath	posh	pulp
badge	loops	stop	lisp	wedge
belk	pooch	cob	nest	hatch
gulp	mash	zen	sulk	says
stilt	scalp	push	zips	watch
zag	thud	cleave	would	kelp
reach	booth	mops	tube	sheathe
stock	wreathe	hasp	chap	bush
thief	gasp	them	put	juice
coop	smoothe	good	rook	thieve
theme	feast	fuzz	loom	chaff
cult	jest	smith	judge	stuff
stood	chief	tots	breathe	seethe
these	god	such	whelp	gin
vat	clang	veldt	smash	zoom
hoof	dune	culp	zing	cliff
clog	wasp	wisp	could	plod
move	heath	guest	mob	rough
puss	tooth	bulk	clasp	nook
doom	lodge	silk	smudge	dodge
talc	jam	moose	kilt	thug
shoes	roof	smut	thing	cling
smooch	gap	soup	fog	news
hook	shove	fez	death	look
took	plebe	bing	goose	

* Consonant clusters are counted as one phoneme.

of 30 third-grade boys and girls (grade 3.8); Group D, 20 fourth-grade boys (grade 4.8).[2]

It is seen from Table 1 that for a variety of children in the early grades, there is a moderate-to-high relationship between errors on the word lists and performance on the Gray paragraphs.[3] We would expect to find a degree of correlation between reading words and reading paragraphs (because the former are contained in the latter), but not correlations as high as the ones we did find if it were the case that many children can read words fluently but cannot deal effectively with organized strings of words. These correlations suggest that the child may encounter his major difficulty at the level of the word—his reading of connected text tends to be only as good or as poor as his reading of individual words. Put another way, the problems of the beginning reader appear to have more to do with the synthesis of syllables than with scanning of larger chunks of connected text.

This conclusion is further supported by the results of a direct comparison of rate of scan in good- and poor-reading children by Katz and Wicklund [1971] at the University of Connecticut. Using an adaptation of the reaction-time method of Sternberg [1967], they found that both good and poor readers require 100 msec longer to scan a three-word sentence than a two-word sentence. Although as one would expect, the poor readers were slower in reaction time than the good readers, the difference between good and poor readers remained constant as the length of the sentence was varied. (The comparison has so far been made for sentence lengths up to five words and the same result has been found: D. A. Wicklund, personal communication). This suggests, in agreement with our findings, that good and poor readers among young children differ not in scanning rate or strategy, but in their ability to deal with individual words and syllables.

As a further way of examining the relation between the rate of reading individual words and other aspects of reading performance, we obtained latency measures (reaction times) for the words in List 2 for one group of third graders (Group C, Table 1). The data show a negative correla-

[2] We are indebted to Charles Orlando, Pennsylvania State University, for the data in Groups A and D. These two groups comprised his subjects for a doctoral dissertation written when he was a student at the University of Connecticut (Orlando 1971).

[3] A similarly high degree of relationship between performance on word lists and paragraphs has been an incidental finding in many studies. Jastak [1946] in his manual for the first edition of the Wide Range Achievement Test notes a correlation of 0.81 for his word list and the New Stanford Paragraph Reading Test. Spache [1963] cites a similar result in correlating performance on a word recognition list and paragraphs.

tion of 0.68 between latency of response and accuracy on the word list. We then compared performance on connected text (the Gray paragraphs) and on the words of List 2, and we found that latency measures and error counts showed an equal degree of (negative) correlation with paragraph reading performance. From this, it would appear that the slow rate of reading individual words may contribute as much as inaccuracy to poor performance on paragraphs. A possible explanation may be found in the rapid temporal decay in primary memory: if it takes too long to read a given word, the preceding words will have been forgotten before a phrase or sentence is completed [Gough, this volume].

The Contribution of Visual Factors to the Error Pattern in Beginning Reading: The Problem of Reversals

We have seen that a number of converging results support the belief that the primary locus of difficulty in beginning reading is the word. But within the word, what is the nature of the difficulty? To what extent are the problems visual and to what extent linguistic?

In considering this question, we asked first whether the problem is in the perception of individual letters. There is considerable agreement that after the first grade, even those children who have made little further progress in learning to read do not have significant difficulty in visual identification of individual letters [Vernon 1960; Shankweiler 1964; Doehring 1968].

REVERSALS AND OPTICAL SHAPE PERCEPTION

The occurrence in the alphabet of reversible letters may present special problems, however. The tendency for young children to confuse letters of similar shape that differ in orientation (such as "b, d, p, q") is well known. Gibson and her colleagues [1962, 1965] have isolated a number of component abilities in letter identification and studied their developmental course by the use of letter-like forms that incorporate basic features of the alphabet. They find that children do not readily distinguish pairs of shapes that are 180-degree transformations (i.e., reversals) of each other at age 5 or 6, but by age 7 or 8, orientation has become a distinctive property of the optical character. It is of interest, therefore, to investigate how much reversible letters contribute to the error pattern of 8-year-old children who are having reading difficulties.

Reversal of the direction of letter sequences (e.g., reading "from" for "form") is another phenomenon that is usually considered to be intrinsically related to orientation reversal. Both types of reversals are often thought to be indicative of a disturbance in the visual directional scan of print in children with reading disability (see Benton [1962] for a comprehensive review of the relevant research). One early investigator considered reversal phenomena to be so central to the problems in reading that he used the term "strephosymbolia" to designate specific reading disability [Orton 1925]. We should ask, then, whether reversals of letter orientation and sequence loom large as obstacles to learning to read. Do they covary in their occurrence, and what is the relative significance of the optical and linguistic components of the problem?

In an attempt to study these questions [I. Y. Liberman, Shankweiler et al. 1971] we devised the list (presented in Table 2) of 60 real-word monosyllables including most of the commonly cited reversible words and in addition a selection of words which provide ample opportunity for reversing letter orientation. Each word was printed in manuscript form on a separate 3″ × 5″ card. The child's task was to read each word aloud. He was encouraged to sound out the word and to guess if unsure. The responses were recorded by the examiner and also on magnetic tape. They were later analyzed for initial and final consonant errors, vowel errors, and reversals of letter sequence and orientation.

We gave List 1 twice to an entire beginning third-grade class and then selected for intensive study the 18 poorest readers in the class (the lower third), because only among these did reversals occur in significant quantity.

RELATIONSHIPS BETWEEN REVERSALS AND OTHER TYPES OF ERRORS

It was found that, even among these poor readers, reversals accounted for only a small proportion of the total error, though the list was constructed to provide maximum opportunity for reversals to occur. Separating the two types, we found that sequence reversals accounted for 15 percent of the total errors made, and orientation errors only 10 percent, whereas other consonant errors accounted for 32 percent of the total and vowel errors 43 percent. Moreover, individual differences in reversal tendency were large (rates of sequence reversal ranged from 4 to 19 percent; rates for orientation reversal ranged from 3 to 31 percent). Viewed in terms of opportunities for error, orientation errors occurred less frequently than other consonant errors. Test-retest comparisons showed that whereas other reading errors were rather stable, reversals—and particularly orientation reversals—were unstable.

Reversals were not, then, a constant portion of all errors; moreover, only certain poor readers reversed appreciably, and then not consistently. Though in the poor readers we have studied, reversals are apparently not of great importance, it may be that they loom larger in importanc in certain children with particularly severe and persisting reading disability. Our present data do not speak to this question. We are beginning to explore other differences between children who do and do not have reversal problems.

ORIENTATION REVERSALS AND REVERSALS OF SEQUENCES: NO COMMON CAUSE?

Having considered the two types of reversals separately, we find no support for assuming that they have a common cause in children with reading problems. Among the poor third-grade readers, sequence reversal and orientation reversal were found to be wholly uncorrelated with each other, whereas vowel and consonant errors correlated 0.73. A further indication of the lack of equivalence of the two types of reversals is that each correlated quite differently with the other error measures. It is of interest to note that sequence reversals correlated significantly with other consonant errors, with vowel errors, and with performance on the Gray paragraphs, while none of these was correlated with orientation reversals (see I. Liberman, Shankweiler et al. [1971] for a more complete account of these findings).

ORIENTATION ERRORS: VISUAL OR PHONETIC?

In further pursuing the orientation errors, we examined the nature of the substitutions among the reversible letters "b, d, p, g."[4] Tabulation of these showed that the possibility of generating another letter by a simple 180-degree transformation is indeed a relevant factor in producing the confusions among these letters. This is, of course, in agreement with the conclusions reached by Gibson and her colleagues [1962].

At the same time, other observations [I. Y. Liberman, Shankweiler et al. 1971] indicate that letter reversals may be a symptom and not a cause of reading difficulty. Two observations suggest this conclusion: first, confusions among reversible letters occurred much less frequently for these same children when the letters were presented singly, even when only briefly exposed in tachistoscopic administration. If visual factors were primary, we would expect that tachistoscopic exposure would

[4] The letter *g* is, of course, a distinctive shape in all type styles, but it was included among the reversible letters because, historically it has been treated as one. It indeed becomes reversible when hand printed with a straight segment below the line. Even in manuscript printing, as was used in preparing the materials for this study, the "tail" of the *g* is the only distinguishing characteristic. The letter *q* was not used because it occurs only in a stereotyped spelling pattern (*u* always following *q* in English words).

Table 4
Confusions Among Reversible Letters. Percentages Based on Opportunities*

Presented	Obtained b	d	p	q	Total Reversals	Other Errors
b	—	10.2	13.7	0.3	24.2	5.3
d	10.1	—	1.7	0.3	12.1	5.2
p	9.1	0.4	—	0.7	10.2	6.9
g	1.3	1.3	1.3	—	3.9	13.3

* Adapted from I. Y. Liberman, Shankweiler et al., *Cortex*, 1971.

have resulted in more errors, not fewer. Second, the confusions among the letters during word reading were not symmetrical: as can be seen from Table 4, "b" is often confused with "p" as well as with "d," whereas "d" tends to be confused with "b" and almost never with "p."[5]

These findings point to the conclusion that the characteristic of optical reversibility is not a sufficient condition for the errors that are made in reading, at least among children beyond the first grade. Because the letter shapes represent segments that form part of the linguistic code, their perception differs in important ways from the perception of nonlinguistic forms—there is more to the perception of the letters in words than their shape (see Kolers [1970] for a general discussion of this point).

READING REVERSALS AND POORLY ESTABLISHED CEREBRAL DOMINANCE

S. T. Orton [1925, 1937] was one of the first to assume a causal connection between reversal tendency and cerebral ambilaterality as manifested

[5] The pattern of confusions among "b, d, p" could nevertheless be explained on a visual basis. It could be argued that the greater error rate on "b" than on "d" or "p" may result from the fact that *b* offers two opportunities to make a single 180-degree transformation, whereas "d" and "p" offer only one. Against this interpretation we can cite further data. We had also presented to the same chilren a list of pronounceable nonsense syllables. Here the distribution of "b" errors was different from that which had been obtained with real words, in that "b–p" confusions occurred only rarely. The children, moreover, tended to err by converting a nonsense syllable into a word, just as in their errors on the real word lists they nearly always produced words. For this reason, a check was made of the number of real words that could be made by reversing "b" in the two lists. This revealed no fewer opportunities to make words by substitution of "p" than by substitution of "d." Indeed, the reverse was the case. Such a finding lends further support to the conclusion that the nature of substitutions even among reversible letters is not an automatic consequence of the property of optical reversibility. (This conclusion was also reached by Kolers and Perkins [1969] from a different analysis of the orientation problem.)

by poorly established motor preferences. There is some clinical evidence that backward readers tend to have weak, mixed, or inconsistent hand preferences or lateral inconsistencies between the preferred hand, foot, and eye [Zangwill 1960]. Although it is doubtful that a strong case can be made for the specific association between cerebral ambilaterality and the tendency to reverse letters and letter sequences [I. Y. Liberman, Shankweiler et al., 1971], the possibility that there is some connection between individual differences in lateralization of function and reading disability is supported by much clinical opinion. This idea has remained controversial because, due to various difficulties, its implications could not be fully explored and tested.

It has only recently become possible to investigate the question experimentally by some means other than the determination of handedness, eyedness, and footedness. Auditory rivalry techniques provide a more satisfactory way than hand preferences of assessing hemispheric dominance for speech [Kimura 1961, 1967].[6] We follow several investigators in the use of these dichotic techniques for assessing individual differences in hemispheric specialization for speech in relation to reading ability [Kimura, personal communication; Sparrow 1968; Zurif and Carson 1970; Bryden 1970]. The findings of these studies as well as our own pilot work have been largely negative. It is fair to say that an association between bilateral organization of speech and poor reading has not been well supported to date.

The relationship we are seeking may well be more complex, however. Orton [1937] stressed that inconsistent lateralization for speech and motor functions is of special significance in diagnosis, and a recent finding of Bryden [1970] is of great interest in this regard. He found that boys with speech and motor functions oppositely lateralized have a significantly higher proportion of poor readers than those who show the typical uncrossed pattern. This suggests that it will be worthwhile to look closely at disparity in lateralization of speech and motor function.

If there is some relation between cerebral dominance and ability to read, we should suppose that it might appear most clearly in measures that take account not only of dominance for speech and motor function,

[6] There is reason to believe that handedness can be assessed with greater validity by substituting measures of manual dexterity for the usual questionnaire. The relation between measures of handedness and cerebral lateralization of speech, as determined by an auditory rivalry task [Shankweiler and Studdert-Kennedy 1967], was measured by Charles Orlando in a doctoral dissertation done at the University of Connecticut [1971]. Using multiple measures of manual dexterity to assess handedness, and regarding both handedness and cerebral speech laterality as continuously distributed, Orlando found the predictive value of handedness to be high in eight-year-old and ten-year-old children.

but also of dominance for the perception of written language, and very likely with an emphasis on the relationships between them. It is known [Bryden 1965] that alphabetical material is more often recognized correctly when presented singly to the right visual field and hence to the left cerebral hemisphere. If reliable techniques suitable for use with children can be developed for studying lateralization of component processes in reading, we suspect that much more can be learned about reading acquisition in relation to functional asymmetries of the brain.

Linguistic Aspects of the Error Pattern in Reading and Speech

"In reading research, the deep interest in words as visual displays stands in contrast to the relative neglect of written words as linguistic units represented graphically." [Weber 1968, p. 113]

The findings we have discussed in the preceding section suggest that the chief problems the young child encounters in reading words are beyond the stage of visual identification of letters. It therefore seemed profitable to study the error pattern from a linguistic point of view.

THE ERROR PATTERN IN MISREADING

We examined the error rate in reading in relation to segment position in the word (initial, medial, and final) and in relation to the type of segment (consonant or vowel).

List 2 (Table 3) was designed primarily for that purpose. It consisted of 204 real-word CVC (or CCVC and CVCC) monosyllables chosen to give equal representation to most of the consonants, consonant clusters, and vowels of English. Each of the 25 initial consonants and consonant clusters occurred eight times in the list, and each final consonant or consonant cluster likewise occurred eight times. Each of eight vowels occurred approximately 25 times. This characteristic of equal opportunities for error within each constant and vowel category enables us to assess the child's knowledge of some of the spelling patterns of English.

The manner of presentation was the same as for List 1. The responses were recorded and transcribed twice by a phonetically trained person. The few discrepancies between first and second transcription were easily resolved. Although it was designed for a different purpose, List 1 also gives information about the effect of the segment position within the syllable upon error rate and the relative difficulty of different kinds of segments. We therefore analyzed results from both lists in the same way; and as we shall see, the results are highly comparable. A list of

Table 5
Table of Phoneme Segments Represented in the Words of List 2

Initial Consonant(s)	Vowel	Final Consonant(s)
p	a	lp
t	æ	dʒ
k	i	v
b	I	ps
d	ɛ	θ
g	ʌ	lt
m	ʊ	st
n	u	sp
w		ts
r		ʃ
l		s
f		ð
θ		ŋ
s		p
ʃ		lk
v		g
ð		tʃ
z		k
t		f
d		m
h		d
pl		z
kl		t
st		m
sm		h

Table 6
Errors in Reading in Relation to Position and Type of Segment. Percentages of Opportunities for Error

Group*	Reading Ability	n	Age Range	Initial Consonant	Final Consonant	All Consonant	Vowel
C_1	Good††	11	9–10	6	12	9	10
C_2	Poor††	11	9–10	8	14	11	16
B	Poor†	18	8–10	8	14	11	27
Clinic	Poor††	10	10–12	17	24	20	31

* The groups indicated by C_1 and C_2 comprise the upper and lower thirds of Group C in Table 1. Group B is the same as so designated in Table 1. The clinic group is not represented in Table 1.
† List 1 (Table 2)
†† List 2 (Table 3)

the phoneme segments represented in the words of List 2 is shown in Table 5.

We have chosen to use phonetic transcription[7] rather than standard orthography in noting down the responses, because we believe that phonetic tabulation and analysis of oral reading errors has powerful advantages that outweigh the traditional problems associated with it. If the major sources of error in reading the words are at some linguistic level, as we have argued, phonetic transcription of the responses should greatly simplify the task of detecting the sources of error and making them explicit. Transcription has the additional value of enabling us to make a direct comparison between errors in reading and in oral repetition.

Table 6 shows errors on the two word lists percentaged against opportunities as measured in four groups of schoolchildren. Group C_1 includes good readers, being the upper third in reading ability of all the third graders in a particular school system; Group C_2 comprises the lower third of the same third-grade population mentioned above; Group B includes the lower third of the entire beginning third grade in another school system; the clinic group contains 10 children, aged between 10 and 12, who had been referred to a reading clinic at the University of Connecticut. In all four groups, the responses given were usually words of English.

Table 6 shows two findings we think are important. First, there is a progression of difficulty with position of the segment in the word; final consonants are more frequently misread than initial ones. Second, more errors are made on vowels than on consonants. The consistency

[7] In making the transcription, the transcriber was operating with reference to the normal allophonic ranges of the phonemic categories in English.

of these findings is impressive because it transcends the particular choice of words and perhaps the level of reading ability.[8]

We will have more to say in a later section about these findings when we consider the differences between reading and speech errors. At this point, we should say that the substantially greater error rate for final consonants than for initial ones is certainly contrary to what would be expected by an analysis of the reading process in terms of sequential probabilities. If the child at the early stages of learning to read were able to utilize the constraints that are built into the language, he would make fewer errors at the end than at the beginning, not more. In fact, what we often see is that the child breaks down after he has gotten the first letter correct and can go no further. We will suggest later why this may happen.

MISHEARING DIFFERS FROM MISREADING

In order to understand the error pattern in reading, it should be instructive to compare it with the pattern of errors generated when isolated monosyllables are presented by ear for oral repetition. We were able to make this comparison by having the same group of children repeat back a word list on one occasion and read it on another day. The 10 children in the clinic group (Table 6) were asked to listen to the words in List 2 before they were asked to read them. The tape-recorded words were presented over earphones with instructions to repeat each word once. The responses were recorded on magnetic tape and transcribed in the same way as the reading responses.

The error pattern for oral repetition shows some striking differences from that in reading. With auditory presentation, errors in oral repetition averaged 7 percent when tabulated by phoneme, as compared with 24 percent in reading, and were about equally distributed between initial and final position, rather than being markedly different. Moreover, contrary to what occurred when the list was read, fewer errors occurred on vowels than on consonants.

The relation between errors of oral repetition and reading is demonstrated in another way in the scatter plot presented as Figure 1. Percent error on initial consonants, final consonants, and vowels in reading is plotted on the abscissa against percent error on these segments in oral repetition on the ordinate. Each consonant point is based on approximately eight occurrences in the list over 10 subjects, giving a total of

[8] For similar findings in other research studies employing quite different reading materials and different levels of proficiency in reading; see for example, Daniels and Diack [1956] and Weber [1970].

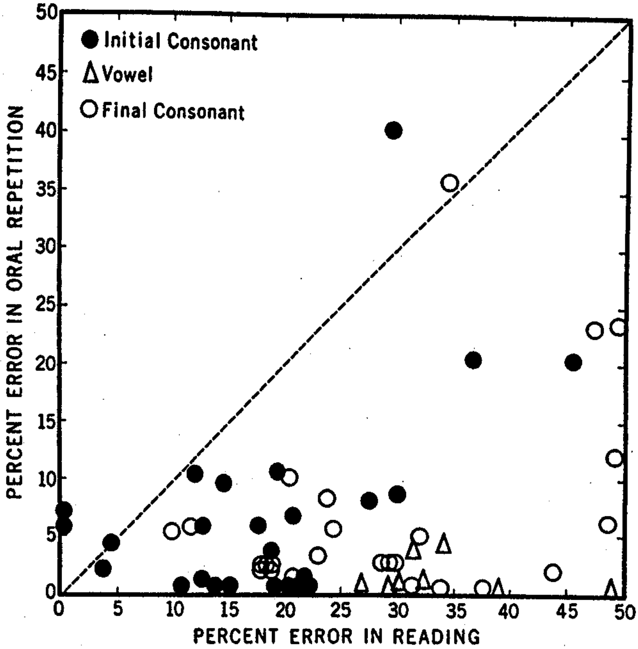

Figure 1. Scatter diagram showing errors on each segment in Word List 2 in relation to opportunities. Percent error in oral repetition is plotted against percent error in reading the same words. Ten subjects.

80. Each vowel point is based on approximately 25 occurrences, giving a total of 250 per point.

It is clear from the figure that the perception of speech by reading has problems which are separate and distinct from the problems of perceiving speech by ear. We cannot predict the error rate for a given phoneme in reading from its error rate in listening. If a phoneme were exactly as difficult to read as to hear, the point would fall on the diagonal line that has been dotted in. Vertical distance from the diagonal to any point below it is a measure of the specific difficulty of reading the phoneme as distinguished from listening to it. Although the reliability of the individual points in the array has not been assessed, the trends are unmistakable. The points are very widely scattered for the consonants. As for the vowels, they are seldom misheard but often misread (suggesting, incidentally, that the high error rate on vowels in reading cannot be an artifact of transcription difficulties).

ACCOUNTING FOR THE DIFFERENCES IN THE ERROR PATTERN IN READING AND SPEECH

The data presented above show that there are major differences between error patterns in reading and speech. However, they should not be taken to mean that reading and speech are not connected. What they do tell us is that reading presents special problems that reflect the difficulties of the beginning reader in making the link between segments of speech and alphabetic shapes.

WHY THE INITIAL SEGMENT IS MORE OFTEN CORRECT IN READING: We have seen that there is much evidence to indicate that in reading the initial segment of a word is more often correct than succeeding ones, whereas in oral repetition the error rate for initial and final consonants is essentially identical.

One of us [I. Y. Liberman 1971] has suggested a possible explanation for this difference in distribution of errors within the syllable. She pointed out that in reading an alphabetic language like English, the child must be able to segment the words he knows into the phonemic elements that the alphabetic shapes represent. In order to do this, he needs to be consciously aware of the segmentation of the language into units of phonemic size. Seeing the word *cat,* being able to discriminate the individual optical shapes, being able to read the names of the three letters, and even knowing the individual sounds for the three letters, cannot help him in really reading the word (as opposed to memorizing its appearance as a sight word), unless he realizes that the word in his own lexicon has three segments. Before he can map the visual message to the word in his vocabulary, he has to be consciously aware that the word *cat* that he knows—an apparently unitary syllable—has three separate segments. His competence in speech production and speech perception is of no direct use to him here, because this competence enables him to achieve the segmentation without ever being consciously aware of it.[9]

Though phonemic segments and their constituent features can be shown to be psychologically and physiologically real in speech perception [A. M. Liberman, Cooper et al. 1967; A. M. Liberman 1968; Mattingly and Liberman 1970] they are, as we have already noted, not necessarily available at a high level of conscious awareness. Indeed, given that the alphabetic method of writing was invented only once, and rather late

[9] The idea of "linguistic awareness," as it has been called here, has been a recurrent theme in this conference. See especially the papers included in this volume by Ignatius Mattingly and Harris B. Savin.

in man's linguistic history, we should suspect that the phonologic elements that alphabets represent are not particularly obvious [Huey 1908]. In any event, a child whose chief problem in reading is that he cannot make explicit the phonological structure of his language might be expected to show the pattern of reading errors we found: relatively good success with the initial letters, which requires no further analysis of the syllable and relatively poor performance otherwise.

WHY VOWEL ERRORS ARE MORE FREQUENT IN READING THAN IN SPEECH: Another way that misreading differed from mishearing was with respect to the error rate on vowels, and we must now attempt to account for the diametrically different behavior of the vowels in reading and in oral repetition. (Of course, in the experiments we refer to here, the question is not completely separable from the question of the effect of segment position on error rate, since all vowels were medial.)

In speech, vowels, considered as acoustic signals, are more intense than consonants, and they last longer. Moreover, vowel traces persist in primary memory in auditory form as "echoes." Stop consonants, on the other hand, are decoded almost immediately into an abstract phonetic form, leaving no auditory traces [Fujisaki and Kawashima 1969; Studdert-Kennedy 1970; Crowder, this volume]. At all events, one is not surprised to find that in listening to isolated words, without the benefit of further contextual cues, the consonants are most subject to error. In reading, on the other hand, the vowel is not represented by a stronger signal, vowel graphemes not being larger or having more contrast than consonant ones. Indeed, the vowels tend to suffer a disadvantage because they are usually embedded within the word. They tend, moreover, to have more complex orthographic representation than consonants.[10]

SOURCES OF VOWEL ERROR: ORTHOGRAPHIC RULES OR PHONETIC CONFUSIONS?

The occurrence of substantially more reading errors on vowel segments than on consonant segments has been noted in a number of earlier reports [Venezky 1968; Weber 1970]; and, as we have said, the reason usually given is that vowels are more complexly represented than consonants in English orthography. We now turn to examine the pattern

[10] This generalization applies to English. We do not know how widely it may apply to other languages. We would greatly welcome the appearance of cross-language studies of reading acquisition, which could be of much value in clarifying the relations between reading and linguistic structure. That differences among languages in orthography are related to the incidence of reading failure is often taken for granted, but we are aware of no data that directly bear on this question.

of vowel errors in reading and ask what accounts for their distribution. An explanation in terms of orthography would imply that many vowel errors are traceable to misapplication of rules that involve an indirect relation between letter and sound.[11] Since the complexity of the rules varies for different vowels, it would follow that error rates among them should also vary.

The possibility must be considered, however, that causes other than misapplication of orthographic rules may account for a larger portion of vowel misreadings. First, there could simply be a large element of randomness in the error pattern. Second, the pattern might be nonrandom, but most errors could be phonetically-based rather than rule-based. If reading errors on vowels have a phonetic basis, we should then expect to find the *same* errors occurring in reading as occur in repetition of words presented by ear. The error rate for vowels in oral repetition is much too low in our data to evaluate this possibility, but there are other ways of asking the question, as we will show.

The following analysis illustrates how vowel errors may be analyzed to discover whether, in fact, the error pattern is nonrandom and, if it is, to discover what the major substitutions are. Figure 2 shows a confusion matrix for vowels based on the responses of 11 children at the end of the third grade (Group C_2 in Table 6) who are somewhat retarded in reading. Each row in the matrix refers to a vowel phoneme represented in the words (of List 2) and each column contains entries of the transcriptions of the responses given in oral reading. Thus the rows give the frequency distribution for each vowel percentaged against the number of occurrences, which is approximately 25 per vowel per subject.

It may be seen that the errors are not distributed randomly. (Chi-square computed for the matrix as a whole is 406.2 with $df = 42$; $p < 0.001$). The eight vowels differ greatly in difficulty; error rates ranged from a low of 7 percent for /I/ to a high of 26 percent for /u/. Orthographic factors are the most obvious source of the differences in error rate. In our list /I/ is always represented by the letter *i*, whereas /u/ is represented by seven letters or digraphs: *u, o, oo, ou, oe, ew, ui*. The correlation (rho) between each vowel's rank difficulty and its number of orthographic representations in List 2 was 0.83. Hence we

[11] Some recent investigations of orthography have stressed that English spelling has more rules than is sometimes supposed—that many seeming irregularities are actually instances of rules, and that orthography operates to preserve a simpler relationship between spelling and morphophoneme at the cost of a more complex relation between spelling and sound [Chomsky and Halle 1968; Weir and Venezky 1968].

VOWEL OBTAINED in Oral Reading (columns); VOWEL PRESENTED in Print (rows)

	ɑ	æ	i	ɪ	ɛ	ʌ	ʊ	u	OTHER
ɑ	87	2		1		4	1	1	4
æ	4	89		1	2	3			1
i			81	1	13				5
ɪ	1	1		93	1	3			1
ɛ	1	4	5	6	79	2	1		2
ʌ	2			3	2	80	2	4	7
ʊ	1	1				5	90	2	1
u	5	1				8	2	74	10

Figure 2. Matrix of vowel errors in reading Word List 2, transcribed in IPA. Each row gives the distribution of responses as percentages of opportunities for each of the eight vowels represented in the list. Eleven subjects.

may conclude that the error rate on vowels in our list is related to the number of orthographic representations of each vowel.[12]

The data thus support the idea that differences in error rate among vowels reflect differences in their orthographic complexity. Moreover, as we have said, the fact that vowels, in general, map onto sound more complexly than consonants is one reason they tend to be misread more frequently than consonants.[13]

It may be, however, that these orthographic differences among segments are themselves partly rooted in speech. Many data from speech research indicate that vowels are often processed differently from consonants when perceived by ear. A number of experiments have shown that the tendency to categorical perception is greater in the encoded stop consonants than in the unencoded vowels [A. M. Liberman, Cooper et al. 1967; A. M. Liberman 1970]. It may be argued that as a consequence of the continuous nature of their perception, vowels tend to

[12] A matrix of vowel substitutions was made up for the better readers (the upper third) of the class on which Figure 2 is based. Their distribution of errors was remarkedly similar.

[13] We did not examine consonant errors from the standpoint of individual variation in their orthographic representation, but it may be appropriate to ask whether the orthography tends to be more complex for consonants in final position than for those in initial position, since it is in the noninitial portion of words that morphophonemic alternation occurs (e.g., *sign–signal*). We doubt, however, that this is a major cause of the greater tendency for final consonants to be misread by beginning readers.

be somewhat indefinite as phonologic entities, as illustrated by the major part they play in variation among dialects and the persistence of allophones within the same geographic locality. By the same reasoning, it could be that the continuous nature of vowel perception is one cause of complex orthography, suggesting that one reason that multiple representations are tolerated may lie very close to speech.

We should also consider the possibility that the error pattern of the vowels reflects not just the complex relation between letter and sound but also confusions that arise as the reader recodes phonetically. There is now a great deal of evidence [Conrad 1964, this volume] that normal readers do, in fact, recode the letters into phonetic units for storage and use in short-term memory. If so, we should expect that vowel errors would represent displacements from the correct vowels to those that are phonetically adjacent and similar, the more so because, as we have just noted, vowel perception is more nearly continuous than categorical. That such displacements did in general occur is indicated in Figure 2 by the fact that the errors tend to lie near the diagonal. More data and, in particular, a more complete selection of items will be required to determine the contribution to vowel errors of orthographic complexity and the confusions of phonetic recoding.

Summary and Conclusions

In an attempt to understand the problems encountered by the beginning reader and children who fail to learn, we have investigated the child's misreadings and how they relate to speech. The first question we asked was whether the major barrier to achieving fluency in reading is at the level of connected text or in dealing with individual words. Having concluded from our own findings and the research of others that the word and its components are of primary importance, we then looked more closely at the error patterns in reading words.

Since reading is the perception of language by eye, it seemed important to ask whether the principal difficulties within the word are to be found at a visual stage of the process or at a subsequent linguistic stage. We considered the special case of reversals of letter sequence and orientation in which the properties of visual confusability are, on the face of it, primary. We found that although optical reversibility contributes to the error rate, for the children we have studied it is of secondary importance to linguistic factors. Our investigation of the reversal tendency then led us to consider whether individual differences in reading ability might reflect differences in the degree and kind of functional asymmetries of the cerebral hemispheres. Although the evidence is at this time not clearly supportive of a relation between cerebral ambilaterality and reading disability, it was suggested that new techniques offer an opportunity to explore this relationship more fully in the future.

When we turned to the linguistic aspects of the error pattern in words, we found, as others have, that medial and final segments in the word are more often misread than initial ones and vowels more often than consonants. We then considered why the error pattern in mishearing differed from misreading in both these respects. In regard to segment position, we concluded that children in the early stages of learning to read tend to get the initial segment correct and fail on subsequent ones because they do not have the conscious awareness of phonemic segmentation needed specifically in reading but not in speaking and listening.

As for vowels in speech, we suggested, first of all, that they may tend to be heard correctly because they are carried by the strongest portion of the acoustic signal. In reading, the situation is different: alphabetic representations of the vowels possess no such special distinctiveness. Moreover, their embedded placement within the syllable and their orthographic complexity combine to create difficulties in reading. Evidence for the importance of orthographic complexity was seen in our data by the fact that the differences among vowels in error rate in reading were predictable from the number of orthographic representations of each vowel. However, we also considered the possibility that phonetic confusions may account for a significant portion of vowel errors, and we suggested how this hypothesis might be tested.

We believe that the comparative study of reading and speech is of great importance for understanding how the problems of perceiving language by eye differ from the problems of perceiving it by ear, and for discovering why learning to read, unlike speaking and listening, is a difficult accomplishment.

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