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ABSTRACT

Reversals in poor and normal second-grade readers were studied in relation to their whole phonological error pattern in reading real words and nonsense syllables. Error categories included sequence and orientation reversals, other consonants, vowels, and total error. Reversals occurred in quantity only in poor readers, with large individual differences. Overall error pattern was similar for good and poor readers. The two types of reversals were uncorrelated in poor readers, therefore not reflecting a single process. No aspect of the error patterns was found to be correlated with cerebral dominance assessed by an auditory rivalry technique. More errors occurred on nonsense syllables than on real words, but the error pattern was similar, suggesting that errors reflect phonological structure more than meaning. Since confusions among reversible letters presented in isolation occurred infrequently, their optical properties cannot be solely responsible for their confusions in reading. Comparisons of substitutions in the real word and nonsense lists support this conclusion. Reading of individual syllables was highly correlated with paragraph reading, suggesting that the beginning reader's problems are more concerned with synthesis of phonological segments than with strategies for scanning connected text. Tables and a bibliography are included. (Author/VJ)

Final Report

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INVESTIGATION OF REVERSAL ERRORS IN READING IN NORMAL AND POOR READERS AS RELATED TO CRITICAL FACTORS IN READING MATERIALS

August 1971

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education
Bureau of Research
(Regional Research Program)

Abstract

Reversals in poor and normal second-grade readers were studied in relation to their whole phonological error pattern in reading real words and nonsense syllables. Error categories included sequence and orientation reversals, other consonants, vowels, and total error. Proficiency of paragraph reading was assessed.

Reversals occurred in quantity only in poor readers, and, even here, there were large individual differences. Overall error pattern was similar for good and poor readers. The two types of reversals were uncorrelated in poor readers and therefore cannot reflect a single process. No aspect of the error pattern was found to be correlated with cerebral dominance assessed by an auditory rivalry technique.

More errors occurred on nonsense syllables than on real words, but the error pattern was similar for the two lists, suggesting that errors reflect phonological structure more than meaning. Since confusions among reversible letters presented in isolation occurred infrequently, their optical properties cannot be solely responsible for their confusions in reading. Comparisons of substitutions in the real word and nonsense lists support this conclusion.

Reading of individual syllables was highly correlated with paragraph reading, suggesting that the beginning reader's problems are more concerned with synthesis of phonological segments than with strategies for scanning connected text.

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Preface

We should like to express our indebtedness to the many associates who assisted in the experimental work of this investigation and in the preparation of the final report.

We are especially grateful to Dr. Charles Orlando, now at Pennsylvania State University, who did much of the testing and contributed generously of his time, effort and experience in many other ways. He was a doctoral candidate in Special Education at the University of Connecticut at the time the major part of the data were being collected.

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Others at the University of Connecticut who assisted in screening and in the collection and processing of the data included Mary Macary, a master's candidate in Special Education; Dr. Sigita Ramanauskas, who was a doctoral candidate in Special Education at the time; and E. W. Capron, a doctoral candidate in Clinical Psychology. A number of other students who provided valuable services include Janet Capron, Ann Dorman, Patricia Tusavitz, David Calchera, and Gail Levine.

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Isabelle Y. Liberman
Donald Shankweiler

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CHAPTER 1

Introduction

Reversal errors in reading and writing have been special concerns in reading research for many years. We can see two principal reasons why reversals have received very much more attention than other kinds of errors. First, we can point to the dominant tendency to view reading primarily as a problem in visual perception, leading to an almost exclusive interest in the perceptual consequences of the optical properties of print and the neglect of the implications of the fact that print represents segments which form part of the linguistic code. Second, reversals are generally thought to be of special importance for understanding reading disability. Indeed, Orton (1925) considered reversals to be so central that he used the term "strephosymbolia" (twisted symbols) to designate specific reading disability. Orton viewed specific reading disability as one element of a developmental syndrome which has at its basis poorly-established cerebral dominance. He attempted to show that children with reading disability tend to have poorly established or unstable lateral preferences, and that they tend to reverse the direction of letters and words in reading and writing. These difficulties were seen as related manifestations of a failure of one cerebral hemisphere to become dominant. This conception of reading disability has been challenged by some workers in the field (Schonell, 1948; Burt, 1950; Vernon, 1960) and supported by others (Zangwill, 1960; Critchley, 1964). The extensive literature dealing with the possible relation between reading disability, motor ambilaterality and cerebral dominance has not resolved the question.

In our view, the question is premature until more is learned about the reversal phenomenon itself. A number of preliminary questions about reversals have not been fully answered. In the first place, it is not known how frequently and consistently reversals occur in beginning readers generally. Secondly, do reversals comprise a constant proportion of all errors? If so, it would be highly misleading to count the reversals a child makes without examining the other errors as well. Our research has been guided by the belief that reversals must be placed in a perspective which can only be gained by studying all errors the beginner makes when confronted with print. Indeed, we are convinced that pursuing the causes of children's reading errors is a necessary first step to gain understanding why learning to read is difficult and why instruction so often fails to have its intended result.

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). 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, g, 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 which incorporate basic features of the alphabet. They find that children do not readily distinguish pairs of shapes which 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 eight-year-old children who are having reading difficulties.

Reversal of the direction of letter sequences (e.g., reading "was" for saw) is another phenomenon which is usually considered to be intrinsically related to orientation reversal. Both types of reversals, as we have said, 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). We should ask whether reversals of letter orientation and sequence loom large as obstacles to learning to read. Do they co-vary in their occurrence, and what is the relative significance of the optical and linguistic components of the problem?

In view of the limitations of earlier work, we saw a need for an experimental study of reversal errors which would take into account the linguistic context as well as the optical properties of the stimuli and would investigate reversals in relation to the other errors the child makes when confronted with the printed word.

Monroe, 1932; Teagarden, 1933; Gates, 1933; Hildreth, 1934; Davidson, 1935; Hill, 1936; Wolfe, 1939; Bennett, 1942) concerned themselves either directly or tangentially with the nature of reversal errors in reading, but, for various reasons, their results are difficult to assess. Some considered only errors of orientation. Several discussed both types, but did not treat the two separately in presenting their results. When they did consider them separately, they did not investigate further the relationship of the two kinds of error to each other, or their relationships to other consonant and vowel errors occurring concomitantly. Special tests to measure reversal tendency have rarely been devised; most investigators culled the reversals from the children's performance on diagnostic reading paragraphs or word lists. Even when special tests were used, no attempt was made to assess the reliability of the findings or to adjust the observations for the opportunities available in the material for making various types of errors. Some studies took into account the effect of whole-word vs. single-letter presentation; usually, the possibility of different error frequencies in meaningful and nonsense material was not considered.

The same shortcomings listed above are found in more recent explorations of reversal error patterns in reading (Hermann, 1959; Tordrup, 1966). Thus, the relationship of sequence and orientation reversals to each other and to different aspects of reading mastery remains uncertain, as does the nature of the general error pattern in the disabled reader. This investigation was designed to provide a more systematic approach to these questions.

We think 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. Though some of the children at this level are well on their way to becoming fluent in reading, a considerable proportion is still floundering and thus provide a sizeable body of errors for examination.

We carried out three experiments. These will be described separately in the succeeding sections, followed by a general discussion and summary of the major results.

The purpose of this experiment was to assess the part reversals play in the problems of the poor-reading child at the end of the second year of instruction.

Method

In an attempt to evaluate the significance of reversals in the error pattern in beginning reading, we devised a word list (presented as Table A in the Appendix) of 60 real-word monosyllables including a selection of primer level sight words, most of the commonly-cited reversible words, and, in addition, a group of CVC words which provide ample opportunity for reversing letter orientation. 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.

Subjects

The subjects for this study were selected from the second grade of an elementary school system located in a small northeastern Connecticut town. A 60-item word list (described above) was administered to the entire second grade population of the school system (N=59). Five children were eliminated as possible subjects. These included two with speech impairment, two who moved from the district before testing could be completed, and one who transferred to the school system after the initial segment of testing had begun.

The 18 children chosen for further study comprised the full lower third of the remaining group in reading proficiency as determined by their total error score on the word list. School records indicated that none of the children had impaired hearing or uncorrected errors of refraction. Fifteen were boys and 3 were girls. Their ages ranged from 7.25 to 9.25 years (mean = 8.25 years). All tested within the normal range of intelligence according to the Wechsler Intelligence Scale for Children (IQ range: 85-126; mean - 98.6).

Procedure

The following tasks were given to all the subjects in the same order on successive days.

1. Real Word List. Each word was printed in manuscript form with a black felt-tip pen on a separate 3" x 5" white index card. The cards were presented individually in the order in which they appear in the list in Table A in the Appendix.

The responses were recorded on magnetic tape as well as being transcribed during the administration, to check on the accuracy of transcription. Each child's responses were analyzed for reversals of sequence and of orientation, for consonant and vowel errors, and for total errors.

The word list was administered twice to each subject—once at the end of the (second) school year and again in the first week of the following school year. Data from the two presentations were combined in scoring the responses of each subject, but were available separately for assessment of test-retest reliability.

2. Gray Oral Reading Test, Form A. Administered by the standard procedure. Raw paragraph scores based on Gray's system of weighting time and number of errors were used to evaluate the subjects' performance, rather than grade level equivalents.

3. Single-letter Test (Tach.) List of 100 items in which a given letter was to be matched to one of a group of five, including four reversible letters in manuscript form (b, d, p, g) and one non-reversible letter (e) which was added as a reliability check. There were 20 such items for each letter. The order of the resultant 100 items was randomized, as was the order of the multiple-choice sequence for each item on the answer form (see Table B in the Appendix for a sample answer form).

The standard was presented tachistoscopically for matching with one of the multiple-choice items on the answer sheets. Tachistoscopic exposure of the 2" x 2" slides of each letter was projected for 1/125 sec. in the center of a 9" x 12" screen mounted six feet in front of the subject. A brief training session was provided for each child.

Error Analysis of Word Transcription

The responses to the stimulus words were scored twice—first, from the transcription made at the time of the test administration, and second, from a separate transcription by another experimenter from the tape recording. Disagreements between scores were infrequent and were easily settled by invoking the rules listed below.

word was read from right to left (e.g., when lap was read as [pæl] or [pleɪ]; form as [fram].

2. Reversal of orientation (RO). Scored when b, d, p, and g were confused with each other, as when bad was read as [dæd], [pæd], or [bæg], if bad was given as [dæb], it was scored as a sequence error instead. Both types of reversal were scored when nip was read as [bIn].

3. Other consonant error (OC). Included all consonant omissions and additions as well as all consonant substitutions other than reversal of orientation. A response could contain both a sequence reversal and a consonant error, as in the case of the response [træp] for the stimulus word pat. It could also contain both an orientation reversal and a consonant error, as in the case of the response [træp] for the stimulus word tab. However, confusions among b, d, p, and g were scored only as reversals of orientation, not as consonant errors.

4. Vowel error (V). Included all vowel substitutions, such as [pIg] for peg. A vowel error was not charged when a consonant error in the response forced a change in the pronunciation of the vowel, provided the vowel sound produced in the response was a legitimate pronunciation of the original printed vowel (response [ræt] for the stimulus word raw).

5. Total error (TE). Simply the sum of all the preceding error types.

In general, the first concern was to assure that scoring was not falsely prejudiced in the direction of any given error category. To this end, certain additional rules were consistently invoked in the few instances when scoring was not immediately self-evident. The stimulus word was viewed in relation to its component printed vowels and consonants as written. The response word was considered phonetically, not in terms of the orthographic transcription of a possible target word. An exception was made when both the stimulus and target words contained vowel digraphs. As noted above, no vowel error was charged when a consonant error in the response produced a change in the pronunciation of the vowel, provided the original printed vowel would be sounded legitimately as read in its new consonant environment.

as [tra], it was, of course, scored simply as a sequence reversal. If it was read as [treɪ], the response was scored as both a sequence reversal and a vowel error. Here, no account was taken of the possible target word tray. The response [træp] would have been scored as a sequence reversal and a consonant error (for the addition of the p). In this case, no vowel error would be scored, since the original printed vowel would be sounded in this way in its new consonant environment (caused by the addition of the p).

Where the final consonant of the stimulus word was part of a vowel digraph as in the case of the word raw, substitutions for the w were viewed as consonant errors (e.g., raw read as [ræt] or [ræm]). Here, as was the case of [træp] as a response for tar, no vowel error was charged, since both the stimulus word and the possible target word (ray) involved vowel digraphs ([o] and [eɪ]).

Results

Which Children Reverse?

The entire second-grade group was rank-ordered with respect to frequency of total errors on the real word list. Nearly all of the reversal errors were found in children ranking in the lower third of the distribution. We, therefore, confined our study to these 18 children who comprised the poorest readers.

Test-Retest Reliability

Since our method of reading assessment was untried, we were concerned to demonstrate its reliability. Test-retest comparisons showed that whereas other reading errors were rather stable, reversals, and particularly sequence reversals, were considerably less so. The test-retest reliability coefficient for the total error was .83; for other consonant errors (OC), it was .69; for vowel (V) errors, .64. Thus, the general error rate among the children is stable, although they tend to give some redistribution of the errors among consonants and vowels. Both types of reversals give lower reliability coefficients ($r_{1,2}$ = .43 for reversals of sequence or RS; $r_{1,2}$ = .50 for reversals of orientation or RO), indicating that they are not highly stable error categories.

It was found that even among these poor readers, reversals accounted for only small proportion of the total of misread letters, though the list was constructed to provide maximum opportunity for reversals to occur (the raw scores of the group appear as Table C in the Appendix). Separating the two types of reversals, we found that sequence reversals (RS) accounted for only 10% of the total errors made, and orientation errors (RO) 15%, whereas other consonant errors (OC) accounted for 32% of the total and vowel errors (V) 43%. Moreover, individual differences in reversal tendency were large: rates of sequence reversal ranged from 4% to 19%; rates for orientation reversal ranged from 3% to 31% (see Table D in the Appendix).

We note, then, that the proportion of the two types of reversals was not the same for all readers. 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 importance in certain children with particularly severe and persisting reading disability. Our present data do not speak to this question.

Since the list provided different opportunities for error in the various error categories, it was of interest to check the proportions in relation to opportunity. Table 1 gives frequencies of errors for RS, RO, OC, and V, each percentaged according to the opportunities for errors of that type. First, we see, in agreement with classroom experience, that letters representing vowels are far more often misread than those representing consonants. Secondly, viewed in terms of opportunities for error, orientation errors occurred less frequently than other consonant errors, but had a greater relative frequency of occurrence than sequence reversals.

Orientation Reversals and Reversals of Sequence: No Common Cause?

When we considered the two types of reversals separately, we found no support for assuming that they have a common cause in children with reading problems. RS and RO were wholly uncorrelated ($r = .03$), whereas V and OC errors correlated .73. That means, of course, that an individual's frequency of misordering letter sequences is entirely unpredictable from his frequency

TABLE 1

Errors as a Function of Opportunity

Experiment I

	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	Single Letter (Tach.)
Errors	136	202	447	598	133
Opportunities	2160	1584	2736	2232	1800
Percent	6.3	12.7	16.3	26.8	7.4

for regarding them both as manifestations of an underlying disturbance, such as failure to develop a consistent automatic left-to-right pattern of scan (Orton, 1937).

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. Intercorrelations among the various measures are displayed in Table 2. It is of interest to note that sequence reversals (RS) correlated significantly with other consonant errors (OC), with vowel errors (V), and moderately with performance on the Gray paragraphs, while none of these is correlated with orientation reversals (RO).

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 and g. The letter q was not used because it appears only in a stereotyped spelling pattern in English words. 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 conclusions reached by Gibson and her colleagues (1962). At the same time, the data lead us to the further conclusion that letter reversals may be a symptom and not a cause of reading difficulty.

Confusions among the four reversible letters are presented as a matrix in Table 3. The matrix shows, with respect to each letter, the frequency with which it was correctly read or replaced by another letter. Each row in the matrix refers to letters occurring in the word list and each column refers to the responses given by the children in oral reading. These frequencies are expressed as percentages of the total occurrences of each letter in the list (i.e., in terms of opportunities for error).

Confusion of b and d is the reversal most commonly mentioned in the literature and was interpreted by Orton (1937) as an instance of "sinistrad scan." It will be seen from Table 3, however, that in this group of children, p is given for b more frequently than is d. Indeed, in the table as a whole, there were slightly fewer occurrences of 180-degree

TABLE 2

Intercorrelation Matrix

Experiment I

	Real Word List Errors				Single Letter (Tach.) Errors	Gray's Paragraphs Scores
	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel		
Total Error	73**	28	93**	91**	19	77**
Reversed Sequence		03	72**	56*	14	45
Reversed Orientation			09	20	04	15
Other Consonant				73**	28	71**
Vowel					08	75**
Tach.						01

Note.—The table contains Pearson product-moment correlation coefficients. The decimals and signs are deleted.

*$p < .05$

**$p < .01$

TABLE 3

Confusions Among Reversible Letters in Real Word List

Percentages Based on Opportunities

Experiment I

Obtained / nted	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
q	1.3	1.3	1.3	——	3.9	13.3

the vertical plane (*b* to *p*, for example). This does not support the view that letter reversals are attributable to reversed direction of scan.

We also learn from the table that errors are essentially confined to confusions among *b*, *d* and *p*. 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 a reversible letter. It indeed becomes reversible when hand printed with a straight segment below the line. (Even in manuscript printing, as was used in preparing the stimulus materials for this study, the tail of the *g* is the only distinguishing characteristic.)

Concerning the confusions among *b*, *d*, and *p*, the truly reversible consonants, most errors involved a single 180-degree transformation about the vertical axis or the horizontal axis, but not both. Presumably, the presence within the alphabet of equivalent or near-equivalent optical shapes is one determinant of confusions among the letters *b*, *d*, *p*, and, by the same reasoning, the lack of congruence between these and *g* accounts for the rarity of the *g* substitution for *b*, *d*, or *p*. This conclusion is also supported by the relatively small frequencies of nonreversal errors (i.e., substitutions outside the set defined by the matrix) for *b*, *d*, and *p* in contrast to *g*.

Can we make sense of the pattern of the actual distribution of errors among the letters which differ in orientation but not in form? Table 3 shows that at least twice as many errors occurred in *b* as on *d* or *p*. We may speculate on why this should be so. It may be relevant that *b* offers two opportunities to make a single 180-degree transformation, whereas *d* and *p* offer only one. But there could also be a phonetic reason for the greater error rates on *b*, in that it offers the reader two opportunities to err by a single articulatory feature (place or voicing) whereas *d* and *p* offer only one opportunity to make a single feature error. This would be consistent with the finding that errors in perception of spoken consonants tend to differ from the presented consonant in only one feature, i.e., in voicing or place of production, but not in both (Miller and Nicely, 1955).

visual or a phonetic interpretation of the error pattern, but further data obtained in Experiment IA on a list of nonsense syllables are also not consistent with a purely visual explanation of the pattern of b, d, p, g confusions. As will be seen in the next section, g was again rarely confused with the other three reversible letters, and b continued to elicit the greatest number of errors. Moreover, the distribution of b errors was different from that which had been obtained with real words, in that b-p confusions occurred only rarely. These results suggest that the nature of the 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.)

We may then ask whether confusions among b, d, and p occur outside of word context. When reversible letters were presented tachistoscopically as isolated shapes, relatively few misidentifications occurred (see Appendix, Table C) and, moreover, error rates on orientation reversals (RO) in reading were completely uncorrelated with reversal rates on these letters presented tachistoscopically. If visual factors were primary, we would expect that tachistoscopic exposure would have resulted in more errors, not fewer, and that the same children who reversed appreciably in one condition would do so in the other. Thus, we may conclude that the characteristic of letter reversibility is not a sufficient condition for confusion. Because the latter shapes represent segments which form part of the linguistic code, their perception differs in important ways from the perception of non-linguistic forms.

Reversals and Other Characteristics of the Word List

Our real word list (Appendix, Table A) included a selection of primer level sight words, some of which are reversible into other words (e.g., on-no, was-saw, now-won) and some of which are not (e.g., boy, of, day). It also included a number of nonsight words, some of which are reversible (e.g., top-pot, lap-pal, nip-pin) and some which are not (e.g., dig, bet, bay).

We investigated the possibility that these two characteristics of might make a difference in the error pattern. Table 4 shows an analysis of the error pattern in terms of the reversibility of the words. The figures in this table represent percentages of the opportunities for errors in the list as divided into reversible and nonreversible sets. It can be seen that among the sight words, reversibility makes no difference whatever in the error pattern: the percentages are nearly identical for all types of errors in the reversible and nonreversible sets of sight words.

In the case of the nonsight words, the data are less clearcut. Here the question of the familiarity and difficulty of the particular words in the two sets (reversible and nonreversible) has an unknown degree of influence on the question of word reversibility as a factor in the error pattern. The fact that the nonreversible set included a number of words like left, felt and form which elicit internal sequence reversal errors undoubtedly increased the number of RS errors in this set. (These words were included in the nonreversible set because in terms of consistent right-to-left direction of scan, they are indeed not reversible into words.) Moreover, since these words are often confused with other words which happen to maintain the same vowel (left-felt, form-from), the relatively low vowel error in the nonreversible set may also reflect the presence of these particular words. In any event, it seems unlikely from the data that reversibility as such can be considered an important factor in determination of the error pattern. The lack of control for difficulty, in addition to the problems just outlined, can certainly account for the differences that are found in our data between the reversible and nonreversible sets.

The same general conclusions about the sight-nonsight and reversible-nonreversible categories are reached when the data for the two categories are considered separately without regard to each other, as presented in Table 5. Here it can be seen that the sight word variable has generally the same effect on all the error types. In the first place, the sight-word set is clearly less productive of errors of all kinds than are the nonsight words. Moreover, the error percentage is roughly the same for all error types among the sight set, with the possible exception of RS errors. This

TABLE 4

Errors as a Function of Opportunity: the Effect of Reversibility on Sight and Nonsight Words

Experiment I

	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel
Reversible Sight	4.9	7.4	7.7	8.3
Nonreversible Sight	4.8	8.3	7.0	7.3
Reversible Nonsight	5.2	11.8	21.7	41.2
Nonreversible Nonsight	10.7	16.7	30.3	30.1

TABLE 5

Errors as a Function of Opportunity

in the

Sight-Nonsight Set and the Reversible-Nonreversible Set

Experiment I

	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel
Sight	4.9	8.0	7.4	7.8
Nonsight	7.0	13.8	23.9	37.6
Reversible	5.2	11.2	17.7	33.0
Nonreversible	8.0	14.6	17.7	19.7
Total List	6.6	12.7	16.3	26.8

than with the nonsight set. When the list is divided into reversible-nonreversible sets, the error pattern reverts to the same general pattern that we found in the list as a whole (with minor variations of error level probably ascribable to the level of difficulty of particular words in the set).

In general, then, the sight factor tends to level out differences among the error types and results in a uniform percentage across error types. Reversibility of the words appears to have no effect that can be separated in our data from the relative difficulty of the sets of reversible and nonreversible words. The pattern of error in these two sets remains largely the same as in the test list as a whole.

In view of these findings, it was considered unfruitful to pursue these relationships further in our later experiments.

The Word List and Reading Fluency

Having presented our second grade readers with an artificial task of reading monosyllabic real words in isolation, we wished to know how performance on such a task related to a conventional measure of reading proficiency. For that purpose we selected the Gray's Oral Reading Test as the most appropriate test available. The obtained Pearson product-moment correlation coefficient (r) was .77 between total errors on our word list and score on Gray's paragraphs, demonstrating a high relationship between error rates on isolated words and on connected text.[1] We would expect to find a degree of correlation between reading words and reading paragraphs (because the former are contained in the latter). However, we would not expect correlations as high as the ones we did find, if it were the case that many children could read words fluently but could not deal effectively with organized strings of words. Indeed, 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.

[1]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 .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.

The purpose of this experiment was to assess the contribution of the phonological structure to the error pattern in reading, independently of lexical meaning.

Method

In order to view the error pattern in the reading of non-meaningful material, we devised a list of 60 CVC nonsense monosyllables including a group of 30 which reverse to common real words and a group of 30 which do not. Both groups of 30 are of equal association value in their natural left-to-right order according to the Glaze tables (Hilgard, 1962). Order of the entire list is randomized. (The list is presented in Table E in the Appendix.)

Subjects

The subjects were the same as in Experiment I.

Procedure

The tasks as outlined in Experiment I were utilized. In addition, the CVC nonsense syllable list described above was administered with the instructions that these were "pretend" words, not "real" words, and that the children should attempt to sound them out as best they could. The responses were transcribed by the examiner and also recorded on magnetic tape. Error categories and scoring rules were the same as in Experiment I.

Results

Test-Retest Reliability

The test-retest reliability coefficients for all the error categories in the real word and nonsense lists can be seen in Table 6. For the nonsense list, the coefficients in all error categories except the reversals of sequence (RS) are consistently high (significant at the .01 level). Reversals of sequence continue to be the least reliable of the error measures; in the nonsense list, the chances for error in this category are essentially random. As was the case in the real word list, the error categories other than reversals in the nonsense list tend to be stable over two administrations of the test lists.

TABLE 6

Test-Retest Reliability Coefficients

for the Various Error Measures in the Real Word and Nonsense Lists

Experiment IA

Type of Error	Real Word List	Nonsense List
Reversed Sequence	43	5
Reversed Orientation	50*	60**
Other Consonant	69**	77**
Vowel	64**	79**
Total Error	83**	74**

Note.—The decimals are deleted.

* $p < .05$

** $p < .01$

It would be expected that, for the beginning reader, a list of nonsense syllables would be more difficult to decode than a list of monosyllables of similar phonological structure which are known by the child to form real words. As can be seen in Table 7, this is indeed the case. The mean number of total errors for the nonsense list is roughly double that of the real word list. (The raw scores for the nonsense list appear as Table F in the Appendix.)

Table 7 also provides a comparison between the two lists of the proportions of the total error accounted for by the various error categories. Once again, as in the real word list, the proportion of reversal errors is small: 8% for RS and 7% for RO as compared with errors of other kinds, 39% for other consonant errors and 46% for vowel errors (see Table G in the Appendix). Moreover, when viewed in terms of opportunities for error, as can also be seen in Table 7, both the pattern and rate of error production for the two types of reversals are remarkably similar in the two lists. The larger number of total errors for the nonsense syllable list appears, then, to be accounted for largely by errors in the other consonant and vowel categories, rather than in reversals.

Orientation Reversals and Reversals of Sequence: No Common Cause?

A comparison between the two lists of the intercorrelations among the error measures, the Tach. Test, and the Gray Oral Reading Test appears in Table 8. Before considering the two types of reversals separately, it is of interest to note the close correspondence between correlations on the two lists for most of the measures represented. Major differences are found only in the reversal measures, particularly in the degree to which they correlate with the OC category of error.

When we consider the two types of reversals separately in the nonsense list, we find, as was true in the real word list, that RS and RO are uncorrelated ($r = .12$, as compared with $r = .03$ on the real word list), whereas the correlation between V and C errors is still high ($r = .68$, as compared with $r = .73$ on the real word list). Thus, there is added support for the view that one cannot assume a common cause between

TABLE 7

Comparison of Errors on Real Word and Nonsense Lists

Experiment IA

Type of Error	Mean Number of Errors		Percentage of Total Error		Percentage of Opportunities	
	Real	Nonsense	Real	Nonsense	Real	Nonsense
Reversed Sequence	8	12	10	8	7	10
Reversed Orientation	11	10	15	7	13	15
Other Consonant	25	56	32	39	16	32
Vowel	33	66	43	46	27	55
Total Error	77	144				

Note.--Data from test and retest are combined for each list.

TABLE 8

Comparison of the Intercorrelation Matrices

on the Real Word and Nonsense Lists

Experiment IA

	Reversed Sequence		Reversed Orientation		Other Consonant		Vowel		Single Letter Tach.		Gray's Paragraphs	
	Real	Nons.	Real	Nons.	Real	Nons.	Real	Nons.	Real	Nons.	Real	Nons.
otal rror	73**	50*	28	32	93**	89**	91**	91**	19	22	77**	70**
eversed equence			03	12	72**	17	56*	44	14	6	45	33
eversed rientation					09	40	20	13	04	22	15	35
ther onsonant							73**	68**	28	10	71**	66**
owel									08	30	75**	57*

Note.—The table contains Pearson product-moment correlation coefficients. The ecimals and signs are deleted.

* $p < .05$

** $p < .01$

Moreover, as can also be seen in Table 8, the lack of equivalence between the two types of reversals is demonstrated in the nonsense list by the fact that each type of reversal again correlated quite differently with the other error measures.

Orientation Errors: Visual or Phonetic?

From the preceding analyses, it can be seen that the overall error pattern in the beginning reader is to a large extent independent of whether the words read are meaningful or not. However, the two lists do elicit markedly different patterns of confusions among the reversible letters in the RO category.

Confusions among the four reversible letters in the nonsense list are presented as a matrix in Table 9. The matrix shows, with respect to each letter, the frequency with which it was correctly read or replaced by another letter. The frequencies are expressed as percentages of the total occurrences of each letter in the list (i.e., in terms of opportunities for error).

As in Experiment I, the letter *g* was again rarely confused with the other three reversible letters. Little information is available about the letter *p* as a possible target for confusability because of the low frequency of occurrence of that letter in the nonsense list. However, the letters *b* and *d* occur in the nonsense list in good quantity and roughly equal numbers.

Table 9 shows that *b* tended to elicit many more reversal errors than the other reversible letters, just as it did in the real word list in Experiment I. This result, of course, again brings into question the importance of optical reversibility as the sole determinant of substitutions among reversible letters. Further comparison of the nature of the substitutions in the two lists provides additional evidence that the substitutions are not an automatic consequence of the property of optical reversibility. In the real word list, for example, *b* tended to be substituted by *p* slightly more often than by *d* (see Table 3 in Experiment I). In the nonsense list, on the other hand, *b* to *p* substitutions occurred only half as frequently as *b* to *d* substitutions.

TABLE 9

Confusions among Reversible Letters on the Nonsense List

Percentages Based on Opportunities for Error

Experiment IA

Presented / Obtained	b	d	p	q	Total Reversals
b	——	22.0	11.1	1.0	34.1
d	5.8	——	1.4	1.4	8.6
p	0.0	0.0	——	0.0	0.0
q	0.3	2.2	0.3	——	2.8

The disparity in substitution pattern in the two lists might have been related to differences in the opportunities to make words by using a particular letter. Though the instructions made it clear that the nonsense list did not contain real words, the children's incorrect responses on both lists often reflected an attempt to form a real word. A check was therefore made in the two lists of the number of real words that could be made by reversing b to p or to d. This count revealed that the nonsense list actually afforded more opportunities to make words by the substitution of p, rather than by the substitution of d. The greater preponderance of d substitutions among the nonsense list RO errors cannot, therefore, be attributed to inflated opportunity.

The fact that the pattern of substitutions among the reversible letters is so markedly different in the two lists certainly points to the conclusion that optical reversibility is not a sufficient cause for letter reversal in reading words.

The Word List and Reading Fluency

In Experiment I, the Pearson product-moment correlation coefficient of .77 between total errors on the real word list and scores on the Gray's Oral Reading Test bespoke a high relationship between error rates on isolated words and on connected text.

As can be seen in Table 8, the correlation between total error on the nonsense list and scores on the Gray's paragraphs is also high ($r = .70$). These correlations suggest again that the child's major difficulty as a beginning reader is at the level of organization and synthesis of syllables—his reading of connected text tends to be only as good or as bad as his ability to decode the syllable.

CHAPTER 4

Experiment II

In this experiment, our interest was to examine, by means of the same real word list (Table A, Appendix), the error pattern in reading in a group in which the incidence of reading failure was expected to be low. Because we were also interested to compare the possible effects of variations in handedness and other indications of cerebral lateralization on the error pattern, the group was selected to include matched groups of right- and left-handed boys.[2] (The relationships between cerebral lateralization of function and reading will be discussed in Experiment III.)

Method

Subjects

Ten left-handed boys were chosen from the second grades of four schools in the towns of Mansfield and Manchester, Connecticut. These two groups, comprising all the left-handed sample in this study, included all the left-handed second-grade boys in the four schools, except three who were excluded because of hearing loss or low IQ (less than WISC Verbal IQ of 85). A group of 10 right-handed boys was matched with the left handers in age, grade and verbal IQ.

Procedure

The Gray Oral Reading Test and the Real Word List as described previously in Experiment I were administered and scored as before.

Results

As in the earlier study, reversals accounted for a small proportion of the total errors made. (The raw scores for this group appear in Table H of the Appendix.) RS and RO each accounted for 12% of the total errors (TE), other consonant (OC) errors accounted for 26% of the total, and vowel (V) errors 50% (see Table I in the Appendix). These proportions compare closely with those obtained in the first study, though the overall error rate for these children averaged less than half that for the selected poor readers in Experiment I.

[2]We are indebted to Charles Orlando, Pennsylvania State University, for the selection of subjects and the lateralization data for this group, which comprised part of his subjects for a doctoral dissertation presented at the University of Connecticut (Orlando, 1971).

Intercorrelations of the various measures are given in Table 10. In contrast to the poor readers of Experiment I in whom we found no relationship between the two types of reversals, here we find them correlated .78. Also, in contrast to Experiment I, RO and RS correlated highly with other measures as well as with each other, suggesting that in beginning readers who are progressing up to expectation, reversal errors have basically the same determinants as other types of errors.

In the main, however, the results show good agreement with the earlier study. Total error on the word list again correlated highly (.70) with performance on paragraphs (the Gray test). Vowel and consonant error also continued to correlate significantly with each other and with the total error. Thus, we find that except for reversals of orientation (RO), the general error pattern is remarkably similar in poor readers and in satisfactory readers. This leads to the conclusion that the problems of learning to read are much the same for beginners whether they are progressing well or poorly. Reversible letters may simply pose an additional source of difficulty for the poor readers.

TABLE 10

Intercorrelation Matrix

Experiment II

	Real Word List Errors				
	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	Gray's Paragraphs
Total Error	81**	86**	90**	91**	70**
Reversed Sequence		78**	70**	64**	77**
Reversed Orientation			82**	66**	72**
Other Consonant				68**	59**
Vowel					58**

** $p < .01$

CHAPTER 5

Experiment III

The purpose of this experiment was to examine the widely held idea that there is a relationship between poor reading and cerebral ambilaterality.

S. T. Orton (1925, 1937) was one of the first to assume a causal connection between reversal tendency and cerebral ambilaterality as manifested 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 a strong case has not yet been made for the specific association between cerebral ambilaterality and the tendency to reverse letters and letter sequences, 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 of assessing hemispheric dominance for speech than hand preferences; because the right ear has a better path to the speech-dominant left cerebral hemisphere, dichotically presented words tend to be more often correctly perceived from the right ear than from the left (Kimura, 1961; 1967). 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 chief innovation of our approach to the problem is that we regard cerebral laterality as a continuously distributed variable rather than a dichotomous one. (There is good reason to reject the idea of dichotomous speech representation.) Zangwill (1960) and others have pointed out that aphasia in left handers tends to take a mild and transitory form. Experimental determination of cerebral speech dominance by unilateral intracarotid injection of sodium amytal also provides strong evidence for bilateral speech representation in some left-handed and ambidextrous individuals (Milner, Branch and Rasmussen, 1966). Thus there is evidence, at least in non-right handers, that the degree of unilateral specialization of the brain for language varies from individual to individual.

Method

Subjects

The relation between reading and auditory rivalry was assessed for three groups of second-grade children: (1) 15 poor readers of Experiment I (the three girls in the group were omitted, because the other groups which are pooled for this analysis contained only boys); (2) the 20 subjects of Experiment II, which includes 10 left-handed and 10 right-handed boys; (3) an additional 22 subjects are included who are of average or above-average IQ (WISC), and who were further selected to include poor, fair and good readers in the second-grade population of a third school system. Thus, 57 subjects in all were available for this study.

Procedure

Determination of lateral cerebral dominance for speech was made by use of an auditory rivalry technique, which one of us (D.S.) had employed for this purpose in a number of previous experiments (Shankweiler and Studdert-Kennedy, 1967; Kirstein and Shankweiler, 1969; Studdert-Kennedy and Shankweiler, 1970). A two-track magnetic tape was prepared consisting of 60 pairs of the synthetic consonant-vowel syllables /ba, da, ga, pa, ta, ka/, prepared on the parallel-formant synthesizer at Haskins Laboratories (Cooper and Mattingly, 1969; Cooper, Rand, Music and Mattingly, 1971). Each of the 15 possible syllable pairs of these stop-consonants-plus /a/ occurred four times, and each syllable occurred equally often at each ear.

The order of presentation of the 60 pairs of stimuli was randomized. The syllables in each pair, presented one to each ear, were synchronized in time of onset and offset. There was a five-second pause between pair presentations. The tape was played back on a Sony 255 stereophonic tape deck through earphones (Realistic 33-195). On each of two testing sessions, the tape was played through twice, yielding two blocks of 120 trials. Initially, the tape was played to each subject with the phones placed on the head in a given position, the same for all subjects. Then the earphones were reversed, the tape rewound and played a second time. Reversal of the phones assures that any unintended differences between channels are distributed over ears and, therefore, cannot bias the results.

The test was administered individually by a trained examiner in a quiet testing room. Before the presentation of the dichotic tape, fifteen of the syllables were presented monaurally to each ear to make sure the subjects could identify the syllables correctly (the Monaural Identification List appears as Table J in the Appendix). This preliminary screening resulted in the exclusion of two subjects. On both the monaural pre-test and the dichotic test (the Dichotic Stimulus Pairs are displayed in Table K in the Appendix), the subject's task was the same: to repeat back each syllable he heard. They were not told that there would be a different syllable arriving at each ear on the dichotic trials, but simply that the words might now be a little harder to hear. All subjects gave only one response on each dichotic trial; none seemed aware of the simultaneous presence of two different syllables. The examiner recorded the responses on a standard answer sheet.

All subjects for this experiment received the Real Word List described in Experiment I. Groups 1 and 2 also had the Gray Oral Reading Test.

Results

Forty-eight of the 57 subjects (84%) obtained a right ear advantage on the dichotic task. Ear advantage was calculated according to an index which had been used by Studdert-Kennedy and Shankweiler (1970): (R-L/R+L)100, where R and L correspond to the total correct identification of syllables presented to the right and left ears, respectively. The index thus has a value of 0 in the condition of complete ambilaterality, positive values ranging from 0 - 100 when there is a right ear advantage, and negative values ranging from o - 100 when there is a left ear advantage. (Tables L, M and N in the Appendix show values of the dichotic index and the reading scores for each of the three groups.)

In order to determine whether there is a relationship between the degree of speech lateralization and reading ability, we carried out intercorrelations on all measures (Pearson r). Correlations were computed between each of the error counts derived from the Real Word List and the following measures derived from the dichotic listening task: (1) the total number, R+L, of correct identifications for both ears, giving a measure of the level of performance which reflects perceptual efficiency under conditions of information overload; (2) the signed dichotic index, (R-L/R+L)100, giving a measure of the degree of left brainedness; (3) the absolute or unsigned value of the dichotic index, (R-L/R+L)100 , giving a measure of the degree of lateralization without regard to which hemisphere is dominant. (The intercorrelations of these measures and the reading scores for Groups 1, 2 and 3 are presented separately in Tables O, P and Q in the Appendix.)

When the pooled data of the three groups are considered (Table 11), we can conclude that the measures of lateralization bear no significant relationship to reading. The same conclusion may be drawn when the three groups of subjects are examined separately. In Groups 1 and 2, the Gray paragraphs score was included in the intercorrelation analysis, also with nonsignificant results. (There is a suggestion of a relationship between R+L, which is not a measure of lateralization but reflects overall performance on the dichotic task, and performance on the Gray paragraphs.) We will consider the implications of these negative findings in the discussion to follow.

TABLE 11

Intercorrelation Matrix

Pooled Data for Groups 1, 2, and 3

Experiment III

	Real Word List Errors				Dichotic Scores		
	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	R+L	Signed Index	Unsigned Index
Total Error	83**	77**	90**	95**	20	04	09
Reversed Sequence		68**	63**	78**	17	02	11
Reversed Orientation			56**	71**	12	09	01
Other Consonant				76**	21	07	04
Vowel					17	01	13
Right + Left						28*	38**
Signed Index							86**

Note.—The table contains Pearson product-moment correlation coefficients. The decimals and signs are deleted.

*$p < .05$

**$p < .01$

CHAPTER 6

Discussion

Reversals of letter sequence and orientation occurred in significant quantity only among the poorer readers in our groups of second graders. Even within the lower third of the class, they accounted (in Experiment I) for only 10% and 15%, respectively, of the total of misread letters, whereas other consonant errors accounted for 32% of the total and vowel errors accounted for 43%. For the nonsense word list (Experiment IA), though the total error was much greater, the error rates for reversals were even less: RS and RO accounted for 8% and 7%, respectively, of the total error. Other consonant errors and vowel errors accounted for 39% and 46%, respectively. Thus, the error pattern for nonsense syllables is similar to that obtained for words, and the larger total number of errors for the nonsense syllable list does not result from an increase in the proportion of reversals.

Our plan of investigation also included a comparison of the error pattern in poor readers with that in children who are progressing normally. A second-grade class in another school system (Experiment II) made less than half as many errors on the word list as the group consisting of poor readers but the distribution of errors was remarkably similar in spite of the markedly lower error rate: RS and RO each accounted for 12% of the total error (compared with 10% and 15%, respectively, for the poor readers of Experiment I); other consonant and vowel errors were 26% and 50% (against 32% and 43%). Thus, for the error categories we used, it appears that the distribution of errors in beginning readers is largely independent of the level of ability, and given that the materials are presented as lists, largely independent of the nature of the task, since the error pattern (in contrast to the error rate) was not greatly affected by whether the list comprised meaningful words or semantically-empty syllables.

Another way to assess the importance of reversals as error categories is to examine their rate of occurrence in relation to the number of opportunities our list offers to make errors of that kind. Among the poor readers it was found that errors as a function of opportunities for the two types of reversals are quite similar in the word list and the nonsense list. For both lists, we find that letters representing vowels are more often misread than those representing consonants, a finding which may be linked to the more complex orthographic representation of vowels than consonants and to fundamental differences between the perception of vowels and consonants in speech (Liberman, Cooper, Shankweiler and Studdert-Kennedy, 1967). Again, the close similarity in the results for nonsense syllables and real words strongly suggests that the error pattern in the beginning reader is more influenced by the phonological structure of words than by their lexical meaning.

Test-retest comparisons showed that whereas other reading errors are highly stable, reversals and particularly sequence reversals, are less so. Individual differences in reversal tendency are also large; only certain poor readers reversed appreciably. Familiarity with the words, as in the case of sight words, appears to level out differences among the error categories, resulting in a more uniform percentage across error types. Thus it is not the case, as has sometimes been believed, that reversal tendency, as such, is the hallmark of the poor reader.

Although we have stressed that reversals of either type do not account for a large proportion of the total error in most of the children we have studied, it may be that reversals loom larger in importance in certain children with particularly severe and persistent reading difficulty. Our clinical experience suggests that this may be so and we intend to explore the question fully in future research.

Orton (1925; 1937) was one of the first to assume a causal connection between reversal tendency and cerebral ambilaterality as manifested by poorly-established motor preferences. It has only recently become possible to investigate the question experimentally by some other means than the determination of handedness, eyedness and footedness. Auditory rivalry techniques (Kimura, 1961; 1967; Shankweiler and Studdert-Kennedy, 1967; Studdert-Kennedy and Shankweiler, 1970) provide a more satisfactory way of assessing hemispheric dominance for speech than hand preferences. Our findings with a dichotic method of assessing hemispheric dominance have been generally negative. We have not found an association between bilateral organization of speech and reversals or any other measure of reading difficulty. These findings are in agreement with others recently reported (Kimura, personal communication; Sparrow, 1968; Zurif and Carson, 1970; Bryden, 1970).[3]

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.

Examination of the intercorrelations among various reading errors showed that in the poor reading group the two types of reversals are wholly uncorrelated. (This was the case not only in real words but with nonsense syllables.) This is a finding of considerable interest since both types of reversals were considered by Orton to be manifestations of an underlying tendency to reverse the direction of scan. That view cannot easily be reconciled with two additional findings: first, among reversible letters, vertical reversals occurred with as great frequency as horizontal reversals; second, confusions among reversible letters rarely occurred when these letters were presented singly, even when briefly exposed in the tachistoscope.

An analysis of the nature of substitutions among reversible letters (b, d, p, g) was carried out. This showed that the possibility of generating another letter by a simple 180-degree transformation is a relevant factor in producing a relatively high rate of confusions among these letters, in agreement with conclusions reached by Davidson (1935) and by

[3] A preliminary factor analysis of the pooled data for Groups 1, 2 and 3 is in agreement with the intercorrelation analysis in finding no common loading between the reading and laterality measures. However, for the 15 children in Group 1, the poor reading group, there is a common factor represented by the RO and both the R+L and the signed index of the dichotic scores. Data on a larger group of poor readers are being collected to check on this finding.

Gibson and her associates (1962).

At the same time, other observations indicated that letter reversals may be a symptom and not a cause of reading difficulty. Two observations suggest this: first, as we have noted, confusions among reversible letters occurred much less frequently for these same children when the letters were presented singly, in brief tachistoscopic administration. If visual factors were primary, we would expect that tachistoscopic exposure would have resulted in more errors, not fewer. Secondly, 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.

The pattern of confusions among b, d, and 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 data from the 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 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.

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 which form part of the linguistic code, their perception differs in important ways from the perception of non-linguistic 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).

Further exploration of the linguistic determinants of children's reading errors is clearly needed. In this connection, the high correlation between reading proficiency on the word list and the paragraphs of the Gray's Oral Reading Test suggests that for the beginning reader, at least, an analytic test consisting of monosyllables can be substituted for a test employing connected text. We would, of course, 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 could read words fluently but could not 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 has the major implication that methods of instruction which stress spelling-to-sound correspondences and other aspects of decoding are more likely to succeed than those methods which leave the child to adduce these relationships for himself. One way or another, the would-be skilled reader must become actively aware that letters of the alphabet represent segments of speech which are in general smaller than the word or syllable (see Liberman, 1971, for a discussion of this point as related to basic research in speech perception).

CHAPTER 7

Conclusions

A concern to discover why learning to read is difficult led to a reexamination of reversals of letter sequence and optically-reversible letters in beginning readers. Reversal errors have been much studied but rarely in relation to the whole error pattern when the beginning reader confronts the printed word. Our plan of investigation was to compare the error pattern for word lists in poor-reading second graders with that in children who are progressing normally. The error categories studied included sequence and orientation reversals, other consonants, vowels and total error. Proficiency of paragraph reading was also assessed for both groups.

Reversals of letter sequence and letter orientation occurred in significant quantity only in the poor readers among the children we studied, and ever among these, there were large individual differences in the tendency to make errors of these kinds. The distribution of errors among the various error categories was much the same for the group of normal readers as it was for the poor readers as a group. The two types of reversals were uncorrelated in poor readers and, therefore, cannot reflect a single process as Orton had implied. Neither type of reversal nor any other aspect of the error pattern was found to be related to individual variations in cerebral dominance for speech as assessed by an auditory perceptual rivalry technique.

As expected, more errors occurred on nonsense syllables than on real words, but the overall pattern of errors was remarkably similar for the two lists, suggesting that, in beginning readers, the errors in reading these materials reflect the phonological structure more than lexical meaning. Confusions among optically reversible letters did not often occur when these were presented in isolation, suggesting that confusions among these letters in reading are not simply an automatic sequence of their optical properties. Differences in proportion of errors for b and d, as well as variations in the substitutions for these letters between the word and nonsense lists lead to the same conclusion.

Reading ability assessed by the analytic tests composed of isolated words was highly correlated with reading proficiency on a conventional paragraphs test. This implies that the problems of the beginning reader may have more to do with synthesis of words from phonological segments than with strategies for scanning connected text. In other words, poor reading of connected text with little comprehension is usually a consequence of reading individual words poorly.

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APPENDIX

TABLE A

Real Word List

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

TABLE B

Single Letter (Tach.) Answer Sheet

E ____________________ DATE ____________ SCHOOL ____________

1.	d	g	p	e	b
2.	b	d	e	p	g
3.	d	g	p	e	b
4.	p	g	b	d	e
5.	d	g	p	e	b
6	b	d	g	p	e
7	e	p	g	b	d
8	d	e	p	g	b
9	b	d	g	p	e
10	e	b	d	g	p

TABLE C

Experiment I

Raw Scores[+] for Each Child

Subject	Real Word List Errors* Total Error	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	Single Letter (Tach.)	Gray's Paragraphs	WISC IQ
ALB	38	6	7	5	20	7	15	126
HAR	44	4	10	18	12	4	17	117
MUR	45	5	13	8	19	12	17	106
TIN	47	3	14	7	23	7	17	90
LOW	56	7	3	17	29	5	15	96
FON	57	10	18	16	13	2	15	99
LEG	57	11	9	15	22	16	10	102
MOR	63	7	11	21	24	6	12	94
ROM	63	7	6	25	25	9	11	115
LEE	72	9	9	13	41	7	8	98
COR	73	6	2	32	33	8	13	91
BUR	76	3	17	31	25	9	5	99
WAU	77	9	7	21	40	7	10	86
COL	91	8	15	27	41	6	16	88
WID	107	6	19	28	54	8	4	95
GRE	107	6	8	41	52	5	1	91
KEL	108	8	21	25	54	11	10	97
SCU	201	21	13	96	71	4	0	85
Mean	76.8	7.6	11.2	24.8	33.2	7.4	10.9	98.6

[+]All scores are error scores except for Gray's paragraphs and WISC IQ.

*Sum of test and retest scores combined.

TABLE D

Experiment I

Relative Frequency of Error Types for Each Child: Real Word List

Percentage of Total Error

Subject	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel
ALB	15.8	18.4	13.1	52.6
HAR	9.1	22.7	40.9	27.3
MUR	11.1	28.9	17.8	42.2
TIN	6.4	29.8	14.9	48.9
LOW	12.5	5.3	30.3	51.9
FON	17.5	31.6	28.1	22.8
LEG	19.3	15.8	26.3	38.6
MOR	11.1	17.5	33.3	38.1
ROM	11.1	9.5	39.7	39.7
LEE	12.5	12.5	18.0	56.9
COR	8.2	2.7	43.8	45.2
BUR	3.9	22.4	40.8	32.9
WAU	11.7	9.1	27.3	51.9
COL	8.8	16.5	29.7	45.0
WID	5.6	17.7	26.2	50.5
GRE	5.6	7.5	38.3	48.6
KEL	7.4	19.4	23.1	50.0
SCU	10.4	6.5	47.8	35.3
Mean	9.6	14.6	32.3	43.3

TABLE E

Nonsense Word List

1.	dor	21.	maj	41.	nug
2.	tir	22.	mik	42.	nam
3.	bed	23.	med	43.	tul
4.	wor	24.	mir	44.	min
5.	gon	25.	mas	45.	gol
6.	wol	26.	dil	46.	nov
7.	tep	27.	rin	47.	ber
8.	raz	28.	dom	48.	maz
9.	nev	29.	bot	49.	mol
10.	gab	30.	tox	50.	bic
11.	dev	31.	wir	51.	riv
12.	ges	32.	boc	52.	mus
13.	ris	33.	dur	53.	nul
14.	nav	34.	nig	54.	bir
15.	gid	35.	bif	55.	nom
16.	nuf	36.	tor	56.	gil
17.	gor	37.	nos	57.	mot
18.	rab	38.	gib	58.	rif
19.	wud	39.	tur	59.	raj
20.	ras	40.	dos	60.	bur

TABLE F

Experiment IA

Raw Scores[+] for Each Child

Subject	Nonsense List Errors* Total Error	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	Single Letter (Tach.)	Gray's Paragraphs	WISC IQ
ALB	109	3	6	37	63	7	15	126
HAR	86	5	11	38	32	4	17	117
MUR	78	5	13	30	30	12	17	106
TIN	112	0	9	41	62	7	17	90
LOW	110	1	2	33	74	5	15	96
FON	95	2	11	39	43	2	15	99
LEG	82	7	5	39	31	16	10	102
MOR	137	4	17	60	56	6	12	94
ROM	131	15	5	68	43	9	11	115
LEE	164	44	9	37	74	7	8	98
COR	192	16	10	76	90	8	13	91
BUR	185	13	9	83	80	9	5	99
WAU	124	13	8	34	69	7	10	86
COL	182	32	8	55	87	6	16	88
WID	137	3	18	50	66	8	4	95
GRE	207	26	8	75	98	5	1	91
KEL	195	8	9	88	90	11	10	97
SCU	272	13	19	132	108	4	0	85
Mean	144.3	11.7	9.8	56.4	66.4	7.4	10.9	98.6

[+]All scores are error scores except for Gray's Paragraphs and WISC IQ.

*Sum of test and retest scores combined.

TABLE G

Experiment IA

Relative Frequency of Error Types for Each Child: Nonsense List

Percentage of Total Error

Subject	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel
ALB	2.8	5.5	33.9	57.8
HAR	5.8	12.8	44.2	37.2
MUR	6.4	16.7	38.5	38.5
TIN	0.0	8.0	36.6	55.4
LOW	0.9	1.8	30.0	67.3
FON	2.1	11.6	41.0	45.3
LEG	8.5	6.1	47.6	37.8
MOR	2.9	12.4	43.8	40.9
ROM	11.4	3.8	51.9	32.8
LEE	26.8	5.5	22.6	45.1
COR	8.3	5.2	39.6	46.9
BUR	7.0	4.9	44.9	43.2
WAU	10.5	6.4	27.4	55.6
COL	17.6	4.4	30.2	47.8
WID	2.2	13.1	36.5	48.2
GRE	12.6	3.9	36.2	47.3
KEL	4.1	4.6	45.1	46.2
SCU	4.8	7.0	48.5	39.7
Mean	7.5	7.4	38.8	46.3

TABLE H

Experiment II

Raw Scores for Each Child

Real Word List Errors*

Subject	Total Error	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel
AND	53	8	11	15	19
BAL	4	0	1	1	2
BRO	1	0	0	0	1
BUR	5	0	4	1	0
CLE	18	2	3	6	7
GIO	40	10	4	5	21
GOU	94	12	11	39	32
LOM	4	0	0	0	4
MCD	9	0	1	1	7
RIV	59	6	3	11	39
BRA	21	1	0	6	14
FIT	19	2	3	2	12
HAR	33	5	5	14	9
KIN	30	3	2	8	17
LAN	25	0	0	1	24
MIS	32	3	4	14	11
NEM	95	5	12	26	52
TUL	59	11	9	9	30
TUR	1	0	1	0	0
WEA	12	2	0	3	7
Mean	30.7	3.5	3.7	8.1	15.4

*Sum of test and retest scores combined.

TABLE I

Experiment II

Relative Frequency of Error Types for Each Child: Real Word List

Percentage of Total Error

Subject	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel
AND	15.1	20.8	28.3	35.8
BAL	0.0	25.0	25.0	50.0
BRO	0.0	0.0	0.0	100.0
BUR	0.0	80.0	20.0	0.0
CLE	11.1	16.7	33.3	38.9
GIO	25.0	10.0	12.5	52.5
GOU	12.8	11.7	41.5	34.0
LOM	0.0	0.0	0.0	100.0
MCD	0.0	11.1	11.1	77.8
RIV	10.2	5.1	18.6	66.1
BRA	4.8	0.0	28.6	66.7
FIT	10.5	15.8	10.5	63.2
HAR	15.2	15.2	42.4	27.3
KIN	10.0	6.7	26.7	56.7
LAN	0.0	0.0	4.0	96.0
MIS	9.4	12.5	43.8	34.4
NEM	5.3	12.6	27.4	54.7
TUL	18.6	15.3	15.3	50.8
TUR	0.0	100.0	0.0	0.0
WEA	16.7	0.0	25.0	58.3
Mean	8.2	17.9	20.7	53.2

TABLE J

Monaural Identification Stimuli

1.	Ta
2.	Ga
3.	Pa
4.	Ka
5.	Da
6.	Pa
7.	Ga
8.	Da
9.	Ga
10.	Ba
11.	Pa
12.	Ta
13.	Pa
14.	Ga
15.	Ba

TABLE K

Dichotic Stimulus Pairs

SAMPLES: a. T-G b. T-B c. B-K

Channel 1		Channel 2	Channel 1		Channel 2	Channel 1		Channel 2
1.	Da	Ga	21.	Ba	Ta	41.	Ka	Pa
2.	Ba	Ga	22.	Da	Ta	42.	Pa	Ta
3.	Ka	Ga	23.	Da	Ba	43.	Da	Pa
4.	Da	Ga	24.	Pa	Da	44.	Ta	Da
5.	Pa	Ga	25.	Ba	Ka	45.	Ta	Ba
6.	Ka	Pa	26.	Da	Ka	46.	Ta	Ga
7.	Ga	Pa	27.	Pa	Ba	47.	Ka	Ga
8.	Da	Ba	28.	Pa	Ta	48.	Pa	Ba
9.	Ka	Ta	29.	Ga	Ta	49.	Ta	Ba
10.	Da	Ka	30.	Ta	Ka	50.	Ka	Da
11.	Ba	Ta	31.	Ka	Ta	51.	Ta	Ka
12.	Ta	Pa	32.	Ta	Ga	52.	Ba	Da
13.	Ba	Pa	33.	Ba	Pa	53.	Ba	Da
14.	Da	Ta	34.	Ga	Ka	54.	Pa	Ka
15.	Pa	Da	35.	Ga	Da	55.	Da	Pa
16.	Ga	Ta	36.	Ga	Pa	56.	Ka	Ba
17.	Ga	Ka	37.	Pa	Ga	57.	Ka	Da
18.	Pa	Ka	38.	Ta	Da	58.	Ga	Ba
19.	Ba	Ka	39.	Ba	Ga	59.	Ta	Pa
20.	Ga	Ba	40.	Ka	Ba	60.	Ga	Da

TABLE 1

Group 1, Experiment III

Reading Scores and Dichotic Index

Subject	Gray's Paragraphs	Real Word List Errors: Total Error	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	Dichotic Scores: R+L	$\frac{R-L}{R+L}(100)$	$\left\|\frac{R-L}{R+L}(100)\right\|$
ALB	15	38	6	7	5	20	127	8	8
HAR	17	44	4	10	18	12	183	4	4
MUR	17	45	5	13	8	19	184	47	47
TIN	17	47	3	14	7	23	181	-9	9
FON	15	57	10	18	16	13	161	5	5
LEG	10	57	11	9	15	22	150	-1	1
MOR	12	63	7	11	21	24	159	34	34
ROM	11	63	7	6	25	25	163	19	19
LEE	8	72	9	9	13	41	164	8	8
COR	13	73	6	2	32	33	172	14	14
WAU	10	77	9	7	21	40	191	22	22
WID	4	107	6	19	28	54	158	30	30
KEL	10	108	8	21	25	54	173	7	7
SCU	0	201	21	13	96	71	148	14	14
GRE	1	107	6	8	41	52	150	1	1

TABLE M

Group 2, Experiment III

Reading Scores and Dichotic Index

Subject	Gray's Paragraphs	Real Word List Errors						Dichotic Scores		
		Total Error	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	R+L	$\frac{R-L}{R+L}(100)$	$\left\vert\frac{R-L}{R+L}(100)\right\vert$
AND	8	53	8	11	15	19	173	13	13
BAL	26	4	0	1	1	2	180	21	21
BRO	35	1	0	0	0	1	181	-20	20
BUR	26	5	0	4	1	0	177	12	12
CLE	24	18	2	3	6	7	162	9	9
GIO	11	40	10	4	5	21	130	-6	6
GOU	11	94	12	11	39	32	140	4	4
LOM	27	4	0	0	0	4	150	-9	9
MCD	21	9	0	1	1	7	199	-16	16
RIV	23	59	6	3	11	39	188	6	6
BRA	27	21	1	0	6	14	206	6	6
FIT	23	19	2	3	2	12	190	8	8
HAR	18	33	5	5	14	9	202	56	56
KIN	21	30	3	2	8	17	163	14	14
LAN	18	25	0	0	1	24	142	-4	4
MIS	26	32	3	4	14	11	193	16	16
NEM	18	95	5	12	26	52	167	16	16
TUL	18	59	11	9	9	30	183	3	3
TUR	30	1	0	1	0	0	183	26	26
WEA	29	12	2	0	3	7	180	30	30

TABLE N

Group 3, Experiment III

Reading Scores and Dichotic Index

Subject	Real Word List Errors: Total Error	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	Dichotic Scores: R+L	$\frac{R-L}{R+L}(100)$	$\left\|\frac{R-L}{R+L}(100)\right\|$
AND	2	0	0	0	2	202	38	38
BER	22	4	0	1	17	181	11	11
BIS	4	0	0	0	4	185	13	13
CHA	22	2	8	5	7	148	6	6
COL	6	1	1	1	3	190	9	9
DOW	5	1	0	0	4	157	14	14
DUE	31	4	2	4	21	173	-8	8
GOR	6	1	0	1	4	167	32	32
JOS	4	0	0	0	4	168	-7	7
KRU	33	5	5	7	16	117	5	5
LOJ	3	2	0	0	1	189	2	2
MAR	10	2	0	2	6	130	16	16
MCL	18	3	2	2	11	142	5	5
OUL	48	7	9	13	19	176	38	38
PAP	20	0	6	3	11	157	7	7
PER	49	11	8	6	24	194	26	26
PET	11	1	0	5	5	175	13	13
RAD	31	6	0	9	16	124	0	0
RUS	16	0	0	2	14	189	31	31
TIT	1	0	0	0	1	177	38	38
VIG	140	31	19	19	71	183	12	12
WHI	3	0	0	0	3	198	7	7

TABLE O

Group 1, Experiment III

Intercorrelation Matrix

	Real Word List Errors					Dichotic Scores		
	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	R+L	Signed Index	Unsigned Index	Gray Paragraph Scores
Total Error	77**	25	94**	91**	23	03	05	85**
Reversed Sequence		10	78**	55*	34	03	13	59*
Reversed Orientation			03	22	08	05	10	07
Other Consonant				75**	25	02	06	75**
Vowel					17	04	02	88**
Right+Left						19	30	40
Signed Index							95**	01
Unsigned Index								12

Note.—The table contains Pearson product-moment correlation coefficients. The decimals and signs are deleted.

*$p < .05$

**$p < .01$

TABLE P

Group 2, Experiment III

Intercorrelation Matrix

	Real Word List Errors				Dichotic Scores			
	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	R+L	Signed Index	Unsigned Index	Gray Paragraph Scores
Total Error	81**	86**	90**	91**	28	07	25	70**
Reversed Sequence		78**	70**	64**	33	05	22	77**
Reversed Orientation			82**	66**	19	17	12	72**
Other Consonant				68**	21	21	06	59**
Vowel					27	06	37	58**
Right+Left						34	44*	45*
Signed Index							73**	03
Unsigned Index								22

Note.—The table contains Pearson product-moment correlation coefficients. The decimals and signs are deleted.

*p < .05

**p < .01

TABLE Q

Group 3, Experiment III

Intercorrelation Matrix

	Real Word List Errors				Dichotic Scores		
	Reversed Sequence	Reversed Orientation	Other Consonant	Vowel	R+L	Signed Index	Unsigned Index
Total Error	98**	91**	91**	98**	01	02	04
Reversed Sequence		85**	86**	96**	04	02	05
Reversed Orientation			85**	84**	00	04	00
Other Consonant				85**	18	02	01
Vowel					02	06	06
Right+Left						36	41
Signed Index							95**

Note.—The table contains Pearson product-moment correlation coefficients. The decimals and signs are deleted.

*$p < .05$

**$p < .01$