Memory & Cognition
1977, Vol. 5 (6), 623-629

Phonetic recoding and reading difficulty in beginning readers

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The results of a recent study (Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977) suggest that good beginning readers are more affected than poor readers by the phonetic characteristics of visually presented items in a recall task. The good readers made significantly more recall errors on strings of letters with rhyming letter names than on nonrhyming sequences; in contrast, the poor readers made roughly equal numbers of errors on the rhyming and nonrhyming letter strings. The purpose of the present study was to determine whether the interaction between reading ability and phonetic similarity is solely determined by different rehearsal strategies of the two groups. Accordingly, good and poor readers were tested on rhyming and nonrhyming words using a recognition memory paradigm that minimized the opportunity for rehearsal. Performance of the good readers was more affected by phonetic similarity than that of the poor readers, in agreement with the earlier study. The present findings support the hypothesis that good and poor readers do differ in their ability to access a phonetic representation.

Many investigators see the root cause of reading disability in school children as a deficit in perceptual learning (e.g., Bender, 1957; Frostig, 1963; Silver & Hagin, 1960). Their research has emphasized the importance of visual processes such as those involved in the identification of letter shapes and the scanning of text. However, critical surveys of such research (Benton, 1962, 1975; Hammill, 1972; Vernon, 1960) produced little hard evidence to support the hypothesis that visual and directional factors figure heavily in most cases of reading disability. This conclusion was reaffirmed by the work of Shankweiler and Liberman (1972), Vellutino, Pruzek, Steger, and Meshoulam (1973), Vellutino, Steger, Harding, and Phillips (1975), and Vellutino, Steger, and Kandel (1972).

In view of the repeated failure to establish visual-perceptual deficits as a major problem in learning to read, several investigators have begun to examine other cognitive prerequisites for reading acquisition, in particular, those relating to the child's primary language abilities. These investigators (e.g., Bloomfield, 1942; Liberman, 1971, 1973; Mattingly, 1972; Rozin & Gleitman, 1977; Shankweiler & Liberman, 1976) have suggested that reading should not be viewed as an independent ability, but as parasitic upon the spoken language. If reading is a derivative of speech and acquired by the child only after he has acquired speech, it is reasonable to consider how learning to read may build upon the earlier language acquisitions of the young child.

Although both good and poor readers speak and understand the language, it may be that poor readers have deficiencies in certain subtle aspects of language development that are not evident even to trained observers. The present research examines this possibility. Specifically, its purpose is to explore the role of phonetic recoding in reading acquisition and to investigate the hypothesis that good and poor beginning readers differ in their ability to access and to use a phonetic representation.

A notable characteristic of language is that the meaning of the longer segments (e.g., sentences) transcends the meaning of the shorter segments (e.g., words); it follows that a listener would have to maintain the smaller units in some temporary store, until a sufficient number of them have accrued to enable him to apprehend the meaning. It has been argued (Liberman, Mattingly, & Turvey, 1972) that a phonetic representation is used for this purpose and that it is uniquely suited to the short-term storage requirements of language. Our own research has emphasized two additional functions of the phonetic representation of spoken language (Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977; Shankweiler & Liberman, 1976). We have speculated that a language user may employ a phonetic representation in order to access his

This paper is based on a Master's thesis by L.S.M. and was supported by grants to Haskins Laboratories from NICHD (HD-01994) and a training grant to the University of Connecticut from NICHD (HD00321-04). The authors express appreciation to Leonard Katz, Sandra Prindle, Michael Turvey, and Robert Verbrugge for advice and criticism on earlier drafts of this manuscript and to Michele Werfelman for assistance in the collection of data. Requests for reprints should be sent to the first author.

mental lexicon and to reconstruct the prosodic information that is crucial to understanding speech. We have also suggested that readers of a language may continue to use a phonetic representation, just as listeners do, rather than develop a new mode of processing for the written language.

There is considerable experimental evidence to support the view that people do employ a phonetic code to store visually presented letters or words, even under circumstances where it is disadvantageous to do so (e.g., Baddeley, 1966, 1968, 1970; Conrad, 1964, 1972; Hintzman, 1967; Kintsch & Buschke, 1969). Typical studies presented subjects with letter or word sequences to be read silently and then recalled. The investigators usually reported that most confusion errors were based on the sound of the letter or word, rather than on its visual appearance.

In addition to these considerations, there is reason to believe that phonetic recoding is of special significance for the beginning reader who is learning how the alphabet works. Consider the relationship between the alphabet and the spoken language. English, unlike the logographic writing system of Chinese and the Japanese Kanji, uses a symbol system, the alphabet, that is keyed largely to the sound structure of the language. If the child has learned something about how the spelling reflects the sound structure, he will be able to offer at least an approximate pronunciation of new words. However, to take full advantage of the benefits inherent in the symbol economy of an alphabet, the reader must be able to employ an analytic strategy, grouping the letter segments into articulatory units and mapping them into speech, rather than treating words as irreducible wholes (Liberman et al., 1977; Shankweiler & Liberman, 1976).

However, in order to use an analytic strategy, the reader must recognize that the alphabet is largely a direct representation of the phonemes in speech. Whereas the recognition of two spoken utterances, such as *bet* and *best*, as different words is sufficient for the comprehension of these as lexical items, the process of mapping the written word onto its spoken counterpart requires, in addition, recognition of the number and identity of the phonemes contained in the spoken word. There is now considerable evidence to suggest that the ability to recognize phoneme segments in speech is a predictor of success in learning to read (Helfgott, 1976; Liberman et al., 1977; Savin, 1972; Zifcak, Note 1).

In view of the evidence that poor readers have difficulty in performing phoneme segmentation tasks, it is appropriate to ask whether poor readers are also deficient in the ability to construct and employ a phonetic representation. Conceivably, poor readers might attempt to retain script as shapes, rather than as phonetic entities. Using a recall memory task, our research group has found evidence to suggest that good and poor readers do differ in their phonetic coding ability (Liberman et al., 1977). In that study, good and poor second-grade readers were presented with sequences of letters for recall. Half of the sequences were composed of rhyming consonants (from the set B, C, D, G, P, T, V, Z), the remainder of nonrhyming consonants (from the set H, K, L, Q, R, S, W, Y). Each of the strings of five uppercase letters was displayed tachistoscopically for 3 sec. The subjects were instructed to print as many of the letters as they could remember, either immediately after presentation or after a 15-sec delay. Their responses were scored both with and without regard to serial position.

Under both recall conditions, the good readers displayed significantly more phonetic interference than the poor readers, as measured by the differences in total errors between the rhyming and nonrhyming sequences. Because of this interaction between reading ability and phonetic similarity, the difference in performance between good and poor readers cannot be explained by supposing that the two reading groups differ in "general memory capacity." The differences also cannot be attributed to a serial-ordering problem in the poor readers, since the effects were significant even when recall was scored without regard to serial position.

It appeared, then, that the phonetic characteristics of the letter names had a differential effect on recall in good and poor readers. From this, it was assumed that the good readers are better able to access and use a phonetic representation in short-term memory than the poor readers. An alternative interpretation, however, would ascribe these findings to differences in rehearsal strategy for the two reading groups (Crowder, Note 2). If the poor readers were able to rehearse fewer letters than the good readers before recall began, the rhyming letters would have less opportunity to interfere. This might give rise to the pattern of results obtained: inferior recall of nonrhyming items by the poor readers, but little difference between the groups on the rhyming letters.

The present experiment was undertaken primarily in an effort to resolve this ambiguity. A paradigm originally devised by Hyde and Jenkins (1969) for a different purpose was adapted for this study, because it permitted us to test memory in a way that minimized the opportunity for rehearsal. The procedure involves a test list of words followed by a recognition list. The subjects are not informed at the time of the presentation of the first list that a subsequent test of recognition memory will follow. Thus, the task appeared to the child merely as a reading task. If differential rehearsal rates were responsible for the earlier results, then differences in phonetic similarity should disappear with this new procedure. However, should the findings of the present study replicate those obtained in the previous research, there would be support for the interpretation that the poor readers have a deficit in accessing or using a phonetic representation derived from script.

A second reason for undertaking the present study was to test the phonetic coding ability of the two groups of readers in a task more nearly resembling a realistic reading situation. This was accomplished by using words, rather than letter strings, as the stimulus items.

METHOD

Subjects

The subjects were second-grade school children in the Mansfield, Connecticut public school system. Children were selected for pretesting on the basis of their total reading grade on the Stanford Achievement Test (SAT), that had been administered by the schools during the fourth month of the school year. In this preliminary screening, children with total reading grades between 3.5 and 5.0 on the SAT were candidates for the good reading group, while those with reading scores between 1.5 and 2.4 were considered for the poor reading group. Final selection of the two reading groups from among these children was made in the seventh month of the school year by administering the word recognition subtest of the Wide Range Achievement Test (WRAT) (Jastak, Bijou, & Jastak, 1965). The criterion for inclusion in the good reading group was a WRAT grade level between 3.1 and 5.0. A child was selected for the poor reading group if his WRAT grade level was in the range of 1.5 to 2.4.

Thirty-seven children (19 good readers and 18 poor readers) met the WRAT criteria for participation in the experiment. Seven subjects (four good and three poor readers) had to be dropped because their data were incomplete due to experimenter error. Another poor reader had to be excused from the experiment because he was unable to read more than 50% of the words on the recognition list (see Scoring Method). Thus, the data analysis was based on the performance of 15 good readers with a mean WRAT grade level of 3.97 (range: 3.1 to 4.5) and 14 poor readers with a mean WRAT grade level of 2.19 (range: 1.5 to 2.4).

The good readers had a mean age of 92.4 months, and the mean age of the poor readers was 94.0 months [$t(27) = .97$, $p < .40$]. The relative intelligence (IQ) of the two reading groups was assessed by the Wechsler Intelligence Scale for Children, Revised Edition (Wechsler, 1974). The good readers had a mean full scale IQ of 114.2 (verbal scale IQ = 113.1, performance scale IQ = 112.5). The full scale, verbal, and performance IQ means for the poor readers were 109.0, 106.4, and 110.9, respectively. The intelligence scores of the two reading groups did not differ significantly on any of the three scales [full scale, $t(27) = 1.05$, $p < .40$; verbal, $t(27) = 1.52$, $p < .20$; performance, $t(27) = .29$, $p < .80$].

Word Lists

The word lists consisted of monosyllables chosen from Part 1 of the Cheek Master Word List (Cheek, 1974). The words (see Table 1) were limited to the first-grade level (1.0-2.0) in order to insure that the poor readers could read the bulk of the words presented, despite their reading handicaps.

The *initial list* was composed of 28 words. The *recognition list* included the 28 words on the initial list and an equal number of words, the foils, not present on that list. Fourteen of the foils were phonetically paired with a word on the initial list. These are the phonetically similar[1] (i.e., rhyming) items.

The phonetically similar foils, additionally, had to meet the requirement that they be as different as possible in visual configuration[2] from all words on the initial list (e.g., my-high, know-go).[3] The decision to make this requirement was motivated by the possibility that some subjects might be responding primarily to the visual appearance of the word, thereby potentially confounding the results. The remaining 14 foils were both phonetically and visually dissimilar to words on the recognition list.

Table 1
List of Phonetically Similar Word Pairs and Phonetically Dissimilar Words

Phonetically Similar Word Pairs		Dissimilar Words	
Old	Foil	Old	Foil
know	go	year	best
my	buy	life	guess
cry	high	each	as
good	could	walk	ride
they	way	help	our
but	what	keep	did
gum	come	not	cake
shoe	two	see	duck
new	do	friend	oh
bird	word	up	off
your	for	jump	box
said	red	told	bring
run	done	yes	face
door	more	gave	brown

Words with phonetically similar foils were equally distributed in each half of the initial list. Each half of the recognition list contained an equal number of words from the four sets: phonetically similar old words, phonetically dissimilar old words, phonetically similar foils, and phonetically dissimilar foils. In addition, half of the rhyming foils preceded their rhyming counterparts from the initial list, while the remaining foils appeared after their counterparts from the initial list.

The words were hand printed in lowercase on white 3 x 5 in. cards, using a black felt-tipped pen. The short letters were .25 in. high, the tall letters .50 in. high.

Procedure

The children were assigned at random to one of two examiners who tested them individually.

Initial list. At the start of the experiment, the child was told that some words were going to be shown to him one at a time. He was instructed to read each word aloud and then to wait until the next word was shown. Each word was shown for as long as it took the child to pronounce it. If the child read the word incorrectly, the experimenter indicated this on the scoring sheet; no attempt was made to correct the child. However, if the child corrected himself spontaneously, the word was scored as having been read correctly.

Recognition list. After completing the initial list, the child was informed that he was going to be shown a second list of words, one at a time. (No mention of this had been made previously.) His task was to read each word aloud and then to say "yes" if he believed the word was on the old list or "no" if he believed it was not. The experimenter recorded both the child's recognition response ("yes" or "no") and whether the child read the word correctly. Before presentation of the recognition list, the examiners verified the child's comprehension of the instructions.

Scoring Method

Reading errors. Any word that was misread on either list was excluded from analysis of that child's recognition judgments. If the child misread a word on the initial list that rhymed with a foil on the recognition list, the recognition response to the phonetically similar foil was also discarded, except in cases where the foil rhymed with another word on the initial list.[3] These exclusions were necessary in order to insure that errors in recognition judgments could be attributed with confidence to phonetic similarity to a word on the initial list. Any child who misread more than 50% of the words on the recognition list was dropped from the experiment.

Recognition judgments. A child's recognition performance on each of the four word sets was expressed as a ratio of the number of recognition errors to the total number of words read correctly in each set.

RESULTS

If the findings of Liberman et al. (1977) can be taken to reflect differences between superior and poor readers in phonetic recoding, then we may expect the following results in the present study: The good readers should make significantly more recognition errors on the rhyming foils than on the nonrhyming foils; the poor readers, on the other hand, should generate approximately equal frequencies of errors on the two types of foils. If, however, both reading groups make equal numbers of errors on each foil type, then we may suppose that opportunity for rehearsal, which was a feature of the previous investigation but not of the present one, may have accounted for the interaction between reading ability and phonetic similarity reported earlier.

Recognition Judgments

Two types of recognition errors will be considered. Of primary interest are the "false-positive" errors: The child reports a word as having occurred on the initial list when, in fact, it was a "new" word. The "false-negative" error, which occurs when the child fails to recognize an "old" word as having appeared on the initial list, will also be considered.

False-positive errors. The mean percentages of recognition errors for the two types of foils (rhyming and nonrhyming) were computed. For the good readers, the error rate was strikingly higher on the rhyming foils (20.4%) than on the nonrhyming foils (4.8%). In contrast, the poor readers showed little difference between the percentage of false-positive errors made on the rhyming foils (16.0%) and the nonrhyming foils (12.4%). Because of the apparent heterogeneity of variance shown by the good readers on the nonrhyming foils relative to rhyming foils, a nonparametric statistic, the Mann-Whitney U Test (Mann & Whitney, 1947), was used to assess the significance of the phonetic characteristics of the foils. For the good readers, the mean difference between the mean recognition errors on the two foil categories was highly significant [$U(15,15) = 26$, $p < .002$], whereas for the poor readers the error difference between rhyming and nonrhyming foils was not significant [$U(14,14) = 80$, $p < .10$].

The interaction between reading ability and foil type (Figure 1) was examined by comparing the difference between the error scores on the rhyming and nonrhyming foils for the two reading groups. The mean error difference was 15.5% for the good readers and 3.5% for the poor readers [$U(15,14) = 23.5$, $p < .002$]. These data strongly support the interpretation of the interaction between reading ability and responses to phonetic similarity that was offered by Liberman et al. (1977).[4]

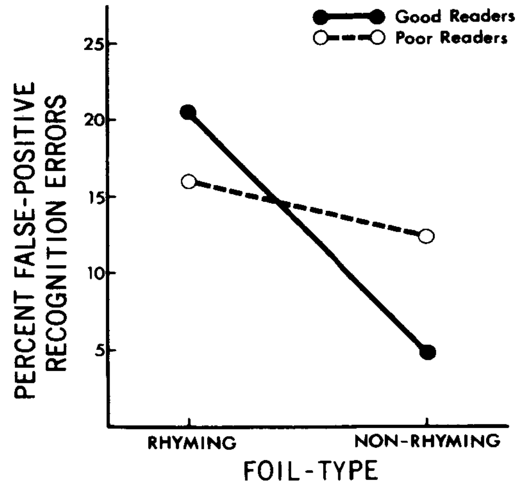

Figure 1. Percent false-positive recognition errors as a function of reading ability and foil type.

False-negative errors. It is somewhat misleading to make a simple division of the old words into those with rhyming foils and those without a rhyming foil. On the recognition list, a word with a phonetically similar foil is indistinguishable from phonetically dissimilar old words until the appearance of its rhyming foil; only those old words that follow their rhyming foil on the recognition list can be said to differ from the nonrhyming old words. In comparing recognition judgments of rhyming and nonrhyming old words, it is reasonable to consider as "phonetically similar old words" only the words that appear after their rhyming foils, and consequently, all other repeated words must be viewed as nonrhyming old words. Using this criterion for categorizing old words, the frequency of false-negative recognition errors for the good readers was 23.8% on the rhyming old words and 28.8% on the nonrhyming old words. The comparable error rates for the poor readers were 18.8% and 19.6%, respectively. The mean false-negative error difference between rhyming and nonrhyming foils was −5.0% for the good readers and −.8% for the poor readers [$U(15,14) = 87$, $p > .2$].

The pattern of false-negative errors reflects a tendency on the part of the good readers to say that a word from the initial list was "old" when it followed its rhyming foil. Thus, for the good readers, words on the initial list that followed their rhyming foils on the recognition list more frequently evoked "yes" judgments than did words that lacked rhyming counterparts. The poor readers showed no such tendency. They made a nearly equal number of "yes" responses to

Table 2
Reading Errors as a Function of Opportunity for Good and Poor Readers

Reading Group		PS_f	PD_f	PS_o	PD_o
Good (n = 15)	Errors	6	1	4	2
	Opportunities	210	210	210	210
	Percent	2.9	.5	1.9	1.0
Poor (n = 14)	Errors	27	30	30	34
	Opportunities	196	196	196	196
	Percent	13.8	15.3	15.3	17.3

Note–PS_f = phonetically similar foil; PD_f = phonetically dissimilar foil; PS_o = phonetically similar old word; PD_o = phonetically dissimilar old word.

phonetically similar and dissimilar words. Thus, the recognition judgments of repeated words reinforce the indications from the analysis of the false-positive errors that good readers have a more persistent phonetic representation in short-term storage than do poor readers.

Reading Errors

Table 2 shows the mean percentage of misread words by the good and poor readers on each of the four sets (phonetically similar old words, phonetically dissimilar old words, phonetically similar foils, and phonetically dissimilar foils) of words. As noted in the description of scoring procedures, recognition judgments of words that were misread on either list were not included in this tally. In addition, when a misread word rhymed with one of the foils on the recognition list, the recognition judgment on that foil was also excluded. As would be expected, the good readers made considerably fewer errors than the poor readers. In fact, 13 of the 15 good readers made no reading errors at all. The poor readers, on the other hand, misread an appreciable number of words. This is a matter for concern only if their errors are unequally distributed among the four sets of words. In that event, one could question the reliability of the differences in false-positive recognition errors, the finding of major interest. However, from inspection of Table 2, it may be seen that roughly the same proportion of misreadings occurred on each of the four sets. This impression was substantiated by the results of a two-factor within-subjects analysis of variance in which phonetic similarity/dissimilarity was tested as one factor (P) and old and new (foil) words were treated as the other factor (R). Neither factor was significant [$F_P(1,13) < 1$; $F_R(1,13) < 1$]. It is apparent that the errors were indeed equally distributed among the four sets of words. Thus, the differences between the reading groups in the distribution of recognition errors on rhyming and nonrhyming foils cannot be attributed to a tendency on the part of the poor readers to make more errors in reading the words of some sets than of others.

DISCUSSION

In a recent study (Liberman et al., 1977), good beginning readers were found to be more affected than poor readers by the phonetic characteristics of visually presented items in a recall task. We attributed this result to differences between the groups' abilities to employ a phonetic representation. The possibility has been raised, however, that differences in rehearsal strategy may account for the finding. The major aim of the present experiment was to clarify the interpretation of the earlier study by using a task in which rehearsal was not a factor. For this purpose, a recognition memory paradigm was used instead of a recall task. The advantage of this procedure is that it does not alert the child to rehearse the target items, because he is not informed in advance that his memory of these items will be tested.

A secondary aim of the present experiment was to demonstrate the differential effects of phonetic similarity on good and poor readers in a task that employs words rather than arbitrary letter sequences, thus extending the earlier findings to a situation that more closely approximates an actual reading task.

The results are summarized in Figure 1: The good readers made fewer recognition errors on the nonrhyming foils relative to their performance on the rhyming foils; in contrast, the poor readers made roughly equal numbers of errors in recognition judgments on the two types of foils. The confirmation of the interaction between reading ability and phonetic similarity with this new task that minimizes possible rehearsal effects suggests that the earlier findings cannot be attributed solely to differences in rehearsal strategy between good and poor readers. The data, therefore, tend to support the hypothesis that the two reading groups differ in their use of a phonetic representation.

It might be concluded, then, that poor readers have a specific difficulty in accessing a phonetic representation derived from script. There is reason to believe, however, that the poor readers' difficulties in making effective use of a phonetic representation are of a more general nature and not limited to recoding from script. The evidence comes from a study reported by Shankweiler and Liberman (1976) that was a sequel to the Liberman et al. (1977) visual recall experiment. The point of that study was to create an auditory analog of the earlier experiment, in which the letter strings would be presented on magnetic tape instead of tachistoscopically. Since phonetic coding is presumably unavoidable when speech is presented auditorily, both reading groups in the auditory experiment would thus be forced to code the incoming speech signal phonetically. If the poor readers' essential difficulty was specific to recoding visually presented script, the auditory version of the recall experiment should yield different results; the statistical interaction between reading ability and phonetic similarity obtained in the previous study should disappear. However, if the interaction remained, it would suggest that the phonetic recoding differences between good and poor readers are not specifically tied to the conversion from print to speech, but rather that the poor readers' deficit extends to heard speech as well as written language.

The results of these new experiments were nearly identical to those using visual recall. As before, the good readers showed significantly more phonetic interference than the poor readers. Thus, it may be concluded that the nature of the poor readers' deficit is related to the accessing and use of a phonetic representation, regardless of the source of the linguistic information. Further investigation of the circumstances that limit access to the phonetic representation is likely to contribute to an understanding of the sources of difficulty in learning to read.

NOTES

1. Word pairs were classified as phonetically similar if they met both of the following criteria: (1) They must share the same vowel sound; (2) they can differ by no more than three consonantal phonetic features in the set of "place," "manner," "voicing," and "nasality" (Wickelgren, 1966). If a set of two words failed to meet either or both requirements, they were considered to be phonetically dissimilar.

2. Given the constraint of having to select words from a first-grade reading list, it was impossible to maintain strict criteria for visual dissimilarity. However, it was important to have some measure of the relative visual similarity of the two foil types to words on the initial list, so that possible visual coding strategies would not confound the results. Accordingly, several informal criteria of visual similarity were followed: (1) The two words had the same number of letters; (2) the initial letters in the words were the same; (3) the initial letters in the words were of the same shape (see below); (4) the final letters in the words were the same shape.

In the following chart, the lowercase letters are grouped into four categories reflecting "similar shape" according to a scheme devised by the authors.

Lowercase Letter Shapes

1. short curved–c o e a s m n r u
2. short straight–v w x z i
3. tall above line–h d b f l t k
4. tall below line–p q g j y

A visual similarity matrix was constructed to compare each foil word with each word from the initial list. The numbers entered in a particular cell indicated the dimensions of visual similarity shared by a particular word pair. The relative visual similarity of the two foil types to the words on the initial list was computed by taking the total number of times each of the four criteria was satisfied for each foil; thus, four totals were obtained for each foil word. Separate t tests were performed on the four visual similarity measures derived for the two types of foils. No t test was significant beyond the .05 level. This suggests that the two sets of foils were roughly comparable in visual similarity to words on the initial list.

3. Some words had more than one rhyming counterpart (e.g., my-high, cry-buy). As a result, some foils were phonetically similar to a second word on the initial list. This somewhat undesirable situation arose with the need to increase the size of the word list, which was constrained by the limits of a first-grade reading list.

4. Although there were no significant differences between the groups in IQ, we were concerned to find a more definitive way of eliminating the possibility that our findings could be attributed to differences in general mental capacity between the two reading groups. For this reason, we made a reanalysis of the data in which the subjects were divided by their position in the distribution of IQ scores (above and below a median split of the distribution) rather than by their reading ability. The results of this reexamination of the data refuted the interpretation that the interaction between reading ability and foil type in the original analysis was due to differences in general mental capacity. First, both good and poor readers were well represented in both high- and low-IQ groups (nine good readers and six poor in the high group, six good readers and eight poor in the low group). Second, although the high-IQ group made fewer errors on both types of foils, there was no interaction between IQ and foil type. The mean error differences between rhyming and nonrhyming foils were nearly identical for the two IQ groups; they were 9.9% for the high-IQ group and 9.7% for the low group [$U(15,14) = 96$, $p > .2$].

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(Received for publication May 27, 1977;
revision accepted August 12, 1977.)