ERRORS IN SHORT-TERM MEMORY FOR GOOD AND POOR READERS

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Abstract. Good and poor readers in the second and third grades repeated 4-item lists of consonant-vowel (CV) syllables for recall in which each consonant shared 0, 1, or 2 features with other consonants in the string. While poor readers, as in previous studies, performed less accurately than good readers, the nature of their errors was the same: Both groups revealed significant effects of phonetic similarity and adjacency on the incidence of errors. These findings suggest that poor readers employ a phonetic coding strategy in short-term memory, as do good readers, though less skillfully.

Children who have difficulty learning to read have consistently been found to perform less well than good readers on a wide variety of short-term memory (STM) tasks (Bauer, 1977; Brady, Shankweiler, & Mann, 1983; Hogaboam & Perfetti, 1978; Jorm, 1983; Katz, Healy, & Shankweiler, 1983; Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977; Mann, Liberman, & Shankweiler, 1980; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; Torgesen, 1982). If, as is generally agreed, text comprehension depends on the ability to preserve temporarily the phonetic form of linguistic input in STM, then a short-term memory deficit may be central to the comprehension and reading fluency problems of poor readers.

Research in the last decade suggests that the deficits poor readers display on STM tasks are related to less efficient phonetic coding processes. This conclusion is supported by three lines of evidence. First, the contrast between reading groups for performance on STM tasks seems to be restricted to procedures with "phonetically recodable" stimuli. When visual stimuli are selected that do not lend themselves to phonetic coding, the performances of good and poor readers are the same. For example, for stimuli such as photographs of strangers, nonsense doodle drawings, or symbols from an unfamiliar writing system, recall by good and poor readers is comparable (Katz, Shankweiler, & Liberman, 1981; Liberman, Mann, Shankweiler, & Werfelman, 1982; Vellutino, Pruzek, Steger, & Meshoulam, 1973). Similarly, in memory for auditory stimuli such as tones that are not readily recoded phonetically, poor readers perform equally well on STM tasks (Holmes & McKeever, 1979). The difference between reading groups for recall of "phonetically recodable" stimuli and the lack of differences in performance for stimuli that are "phoni-   

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cally unreocdeable" highlight the poor readers' difficulty with the use of a phonetic code.

A second line of evidence finds that manipulations of certain phonetic properties of stimuli in an STM task generally have less effect on the performance of poor young readers than on that of the good readers (Brady et al., 1983; Liberman et al., 1977; Mann et al., 1980; Mark, Shankweiler, Liberman, & Fowler, 1977; Olson, Davidson, Kliegl, & Davies, 1984; Shankweiler et al., 1977). With stimuli in which there is a low density of phonetic confusability (i.e., nonrhyming items), good readers' recall is superior. However, if a high density of confusability is present, the performance of good readers is impaired much more than that of poor readers. It has been supposed that this interaction, also found for adults (Baddeley, 1966; Conrad, 1972), results from the fact that the good reader is better able to form a sufficient phonetic code for the maintenance of information in STM. Stimuli that introduce confusion among the phonetic representations in STM, such as strings of rhyming words, therefore tend to have a greater effect on the performance of the more skilled readers.

Third, and of primary concern to us here, is evidence that poor readers may make use of a phonetic code, and not some other coding strategy, but may do so less accurately or efficiently than do good readers (Katz, 1982). Earlier, Conrad (1971) had reported that children 5 years of age or older produced the same pattern of results on STM tasks as do adults. These children had better recall for nonrhyming sets of pictures than for rhyming sets. In contrast, children younger than 6 years old did not show a difference in recall for the nonrhyming set. This study raised the question of whether young children might initially be using some other, non-phonetic, coding strategy in short-term memory. However, more recent research with even younger children (4 yrs) has found the adult pattern, suggestive of phonetic coding (Alegria & Pignot, 1979). That is to say, in the Alegria and Pignot experiments 4-year-old children recalled nonrhyming items better than rhyming items, leading the authors to conclude that by 4 years of age children are already using a phonetic code to store and organize information in short-term memory. Thus, at the present, questions must be raised as to whether there are developmental changes in the type of code employed in short-term memory and, in extension, whether poor readers are indeed using a nonphonetic strategy.

Several findings compel us to reconsider this issue. Using a paradigm that tested recall for time periods longer than the assumed limits of STM, one investigator (Byrne & Shea, 1979) did obtain evidence that poor readers were able to use a phonetic code (albeit poorly) when forced to do so by pseudoword stimuli, but otherwise tended to favor a semantic code (though this has not been replicated [Winbury, 1984]). However, when errors made by poor readers were examined for a standard short-term memory task, there was no indication that poor readers were using a semantic strategy (Brady et al., 1983). Instead, their errors, like those of good readers, indicated that the stimuli were being processed phonetically. Out of 437 intrusion errors (items that were not in the original list) by both reading groups, only one appeared to have been a possible semantic error ("station" for "train"); the vast majority of the remainder could be accounted for in terms of the phonetic units present in the particular string and the preceding string. What was noteworthy was that both reading groups appeared to be using a phonetic coding strategy, although the incidence of recombinations (transpositions) of the phonetic information was significantly more frequent for the poor readers.
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In sum, present evidence is consistent with a hypothesis that the deficit of poor readers on STM tasks has its origin in deficiencies in creating and maintaining a phonetic code. The poor readers' specific difficulty with "phonetically recodable" stimuli, reduced sensitivity to rhyme, and greater frequency of phonetic errors of transposition all support this conclusion.

Most of the studies of short-term memory for good and poor readers have assessed performance by calculating the number of items correctly reported. Analyzing the nature of errors, rather than just the incidence of errors, offers a way to determine how good and poor readers are actually functioning in STM tasks. In the last study mentioned above (Brady et al., 1983), a preliminary effort was made to do this and the results proved interesting. The occurrence of transposition errors for good and poor readers pointed to the use of a phonetic code by both reading groups rather than revealing an alternate strategy for the poor readers. Yet the higher frequency of these errors for poor readers was suggestive of reading group differences in phonetic processing skills. However, the lists in that study had not been designed to allow the rigorous analysis of errors carried out in recent studies of STM in adults (cf. Drewnowski, 1980; Ellis, 1980), so the results are tentative.

Given the importance of short-term memory for language processing and the evidence of STM deficits in poor readers, we thought it worthwhile to conduct a more analytic study of errors in STM for good readers and poor readers. Accordingly, two experiments were conducted in which the nature of the items in the memory lists was controlled. We manipulated the phonetic similarity of the initial consonants as suggested by Ellis (1980). Nonsense syllables were selected as stimuli for two reasons: 1) The small number of semantic errors in a study of children's memory (Brady et al., 1983) and the complete lack of such errors by adults (Drewnowski & Murdock, 1980) suggests that semantic information is not the critical dimension. This conclusion is also supported by the finding that recall level by good and poor readers for sentences is not influenced by whether the sentences are meaningful or anomalous (Mann et al., 1980). 2) With nonsense syllables it is easier to control the distinctive features of the stimuli. Following Ellis's design, lists of nonsense syllables were constructed such that items in the strings shared 0, 1, or 2 features of the initial consonant. This permitted us to determine the effects of the phonetic structure of the materials on the pattern of errors, including that of phonetic similarity on the incidence of transposition errors between adjacent items. Analysis of such effects as they relate to reading ability and the accuracy of recall can provide information on the use of phonetic coding by good and poor readers.

Experiment 1

Methods

Subjects. In Experiment 1, the subjects were second-grade children from two elementary schools in a suburban school district in Rhode Island. A school reading specialist, a principal, and the classroom teachers helped to pre-select the poorest readers and the best readers from the second-grade classes. In a supplementary screening procedure, the Word Attack and Word Recognition subtests of the Woodcock Reading Mastery Tests, Form A (Woodcock, 1973), and a test of receptive vocabulary, the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn 1981), were administered to the children.
Inclusion in the study was determined by the following criteria: 1) To insure valid classification as a good or poor reader, the scores on the two Woodcock subtests had to be consistent. 2) In order to restrict the range of IQ scores, only subtests with scores from 90 to 135 on the PPVT were eligible for further testing. 3) Given the evidence that STM span increases with age (cf. Dempster, 1981), subjects were selected whose ages fell within the limited range of 88 to 100 months.

Twenty-eight children satisfied the requirements for participation in the study. Based on the scores that were obtained on the reading tests, two groups were formed that were non-overlapping in reading level. The 14 children who qualified as good readers were well beyond the end of second-grade reading performance (testing was done in the spring) with a mean reading grade level of 5.0. The 14 children labeled poor readers had an average reading grade level of 2.1, and lagged considerably behind their peers. The IQ scores, as determined by the PPVT, did not differ significantly. The mean IQ score for the good readers was 114, for the poor readers 111. The reading groups also did not significantly differ in age. The good readers had a mean age of 96.1 months, the poor readers had a mean age of 96.4 months.

Materials and procedure. The materials comprise lists of four nonsense syllables presented auditorily in three practice trials and twelve test sequences. In all sequences the stimuli were the consonant-vowel (CV) syllables /Sø/, /[ø]/, /Gø/, and /Kø/. In these syllables, the vowel is held constant, and the initial consonants share 0, 1, or 2 phonetic features. The four syllables can be combined into 6 possible pairs, two of which share 0 features, two which share 1 feature, and two which share 2 features (as detailed in Table 1). The trials consisted of randomizations of these four syllables in which each consonant occurred only once per list and three times at each of the serial positions 1 to 4. For the six stimulus pairs, each occurred twice (once in each order, e.g., /Sø/, /[ø]/, and /Gø/, /Sø/) at each of the serial positions 1 and 2, 2 and 3, and 3 and 4.

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The practice trials and test sequences were read with a neutral intonation by a phonetically-trained male speaker and recorded on magnetic tape. The materials were presented to subjects through headphones. Within each list
the syllables were spoken with a neutral prosody at the rate of one per second.

Each child was tested individually for two sessions in a small room provided by the school. The first session consisted of the screening procedure, the second the memory task. In the second session the practice trials were presented (repeated if necessary), followed by the test sequences. For each trial, subjects were instructed to repeat the items in the order they had been presented, as soon as the list ended.

Results and Discussion

In a preliminary analysis of the data, the number of correct responses was tabulated in terms of item order and serial position, as is customarily done in studies of the short-term recall in good and poor readers. The innovation was to further analyze the errors qualitatively in relation to the syllables that were adjacent to the target syllable in the test sequence, and in relation to the phonetic features of the target syllable.

Analysis of correct responses. Since the same items were presented on each trial, varying only in terms of order, an order-correct scoring procedure was adopted. A response was considered correct only if it had been assigned to the appropriate serial position. Figure 1 shows the mean number correct at each serial position for each group of subjects. Consistent with earlier studies the good readers were notably more accurate overall than the poor readers, $F(1,26) = 9.99, p = .004$. Both groups showed a significant effect of serial position, $F(3,78) = 36.46, p < .001$.

![Figure 1](image_url)

Figure 1. Experiment 1: The mean number of items correctly reported plotted by serial position.
Analyses of covariance using IQ and age as the covariates were conducted to evaluate whether the obtained differences in performance might be attributed to differences in age or intelligence between good and poor readers in our sample. Neither analysis altered the pattern of results: with IQ as the covariate the good readers were still superior in recall, F(1, 25) = 8.72, p = .007; likewise with age as the covariate, F(1, 25) = 9.47, p = .005.

Thus, it was clear that the characteristic differences in STM recall between good and poor readers were obtained with the present task. Having replicated this pattern, we turned our attention to the nature of the errors for both reading groups.

Error analysis. The errors were first categorized as either misplacements of phonetic information that had been in the string, or as errors of omission (no response) or substitution errors (phonemes that were not in the original list). For both good and poor readers, the majority of errors were the first category, phonemes that had occurred elsewhere in the string, F(1, 26) = 56.01, p < .001. Since the vowel was the same for all items, it is not possible to determine whether these order errors are phoneme transpositions or entire syllable order errors.

However, the construction of the present experiment, using phonemes that differ systematically in shared features, does allow us to examine the conditions under which these order errors occurred. Two parameters were measured. First, an error was evaluated as having been, in the original string, adjacent to the target or nonadjacent (e.g., target string "Go, Za, Ka, Se," reported string "Go, Sa, Ke, Za": original location of misreported items was nonadjacent to error position). Second, an error was scored in terms of the number of features shared between the substitute response and the target item (e.g., error /G/, target /K/: two features in common).

As shown in Figure 2, the source (i.e., original location) of substituted stimuli was a significant factor both for good and poor readers. Errors were significantly more likely to involve a syllable adjacent to the target than a nonadjacent syllable, F(1, 26) = 11.44, p = .002. This suggests that the subjects had retained some information about the relative position of items in the original string even when they were unable to make a fully accurate report.

The second qualitative scoring procedure, which evaluated the phonetic similarity between errors and target stimuli, is more central to our interest in the coding skills of good and poor readers. Would the incidence of order errors be greater for stimuli that shared two features than for those with one or none in common? A significant effect of phonetic similarity was obtained, F(2, 52) = 7.93, p < .001, underscoring the phonetic basis for storage in STM. Yet the effect did not differ for good and poor readers, suggesting that both reading groups were relying on phonetic representation.

In Figure 3, the effects of feature similarity on the occurrence of errors is plotted for the order errors involving both adjacent and nonadjacent target stimuli. Here it can be seen that there is a tendency for nonadjacent errors to be more influenced by phonetic similarity than for adjacent errors (adjacency x similarity: F(2, 52) = 2.72, p = .075). Another way of viewing this tendency is in terms of the distinction between memory for item identity and memory for order (Healy, 1975). In this analysis, adjacent errors are
Figure 2. Experiment 1: The mean number of times the error consisted of an item from a nonadjacent or an adjacent position.

Figure 3. Experiment 1: Analysis of feature similarity effects for adjacent and nonadjacent types of errors. The number of shared features for the reported item and the target.
more likely to be strictly order confusions, while more distant mistakes, which are subject to effects of phonetic similarity, are more likely to be "item" confusions reflecting poor retention of information. This pattern was obtained equally for good and poor readers as indicated by the lack of an interaction between reading group, similarity, and adjacency (p > .5).

In sum, in this experiment poor readers were found to recall significantly less information than did the good readers. However, like good readers, their errors consisted largely of information that had been in the string, reported in the wrong order, rather than errors of omissions or substitutions. Further analyses showed that these order errors revealed significant effects of adjacency and of phonetic similarity. Thus the errors of poor readers show the same systematic effects of processing as do the errors of good readers, but occur at a higher rate. The implication of this would seem to be that poor readers employ the same coding strategy as do good readers but less effectively.

Experiment 2

To determine the generality of the results to other consonants and other classes of phonemes, good and poor readers were tested on a second set of items consisting of syllables that started with the consonants /Mæ/, /Næ/, /Bæ/, and /Kæ/. This task was designed to allow a further investigation of the phonetic factors in STM. In addition to a same-vowel condition, a mixed-vowel set was employed to further explore the nature of order errors. In this condition, it is possible to analyze whether order errors consist of transposition of phonetic segments (e.g., /M1/ /Næ/ for /N1/, /Mæ/) or of syllable misorderings (e.g., /Mæ/, /N1/ for /N1/, /Mæ/). In this way we hoped to make a more fine-grained analysis of the processing strategies of good and poor readers.

Subjects

The same subjects were recruited for participation in Experiment 2, conducted in the spring of the following school year (3rd grade). Four children were no longer available, two good readers and two poor readers. The remaining children were reevaluated for inclusion in the study, in accord with the criteria outlined for Experiment 1. For all subjects, placement in a reading group was the same as it had been the previous year. Additional children were screened to increase the number of subjects in each group. Two children qualified as good readers and four as poor readers bringing the group sizes to 14 good readers and 16 poor readers.

As before, the reading groups were non-overlapping in reading level. The 14 good readers had a mean reading grade level of 8.7. The 16 children who were labeled poor readers had a mean reading grade level of 2.9. The PPVT IQ scores did not differ significantly for the reading groups: good readers, \( \bar{x} = 113 \); poor readers, \( \bar{x} = 111 \). Nor did the ages significantly differ: good readers, \( \bar{x} = 107.2 \) mos.; poor readers, \( \bar{x} = 108.3 \).

Materials and Procedure

Experiment 2 was designed to be exactly parallel to Experiment 1 with different stimulus sets. A trial again consisted of four nonsense syllables presented auditorily, and the subjects were asked to repeat the list in the
order of presentation. There were now two conditions, a same-vowel set and a mixed-vowel set. The construction of the test sequences was identical to Experiment 1. The initial consonants of the test items in each set again had 0, 1, or 2 phonological features in common with the other stimuli selected (see Table 2). In the same-vowel condition the stimuli were /Ma/, /Na/, /Ba/, and /Ke/. In the non-rhyme set, the consonants were randomly paired with the vowels /a/, /i/, /e/, /æ/, /ə/, /aɪ/, /eɪ/, /ʌ/, and /u/ (with the stipulation that CV combinations sounding like real words were excluded).

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The preparation of stimulus tapes and the method of testing also mirrored the procedures adopted in Experiment 1, except that each child was tested for three sessions (one screening session and two memory-task sessions). In each memory-task session a subject would have three practice trials (repeated if necessary) and six test trials for one condition (e.g., same vowel), followed by three practice trials (or more) and six test trials for the other condition (e.g., mixed vowel). The order of test conditions was reversed for the second session. Within each reading group, half of the subjects began with the same vowel condition, half with the mixed vowel set.

Results and Discussion

The scoring methods used in Experiment 1 were employed. The results will be presented jointly for the two vowel conditions. First, the correct response data will be discussed, followed by the error analysis results.

Analysis of correct responses. In Figure 4 the mean number correct at each serial position is plotted for the two vowel sets, same vowel and mixed vowel. In these plots, the data have been analyzed only for consonant information. Thus, in this analysis the vowel responses were not scored. Except for recall being a little better for all subjects, as expected for older children, the results replicate those in Experiment 1. Good readers were superior to poor readers in recall for both the same vowel set, \( F(1,28) = 14.25, \ p < .001 \), and the mixed vowel set, \( F(1,28) = 5.64, \ p = .05 \). In addition, the serial position effect was significant for both vowel conditions: same vowel, \( F(3,26) = 19.52, \ p < .001 \); mixed vowel, \( F(3,26) = 18.63, \ p < .001 \).
Figure 4. Experiment 2: The mean number of consonants correctly reported plotted by serial position.

Figure 5. Experiment 2: The mean number of consonants correctly reported replotted for each reading group.
Interestingly, recall of consonants appears to be independent of the vowel environment. There was a striking lack of difference in error rate for consonants for the two vowel sets, $F(1,38) = .00, p > .99$, as shown in Figure 5. That this held for both reading groups is supported by the lack of a group x test interaction, $F(1,28) = 2.43, p = .13$.

In most memory studies, the consonants are not scored in isolation, but rather the entire response is scored as correct or not. We will now present the data in this fashion, counting a response as correct only if both the consonant and vowel were accurately reported. Scoring the entire syllable, a substantial difference in accuracy emerges for the memory sets, $F(1,28) = 146.49, p < .001$. This can be seen in Figure 6. Of course, the error rate for the same-vowel set is the same as plotted for the consonant scoring, since subjects do not make mistakes on the vowels in this task. This is not so for the mixed vowel set where the amount of information to be recalled is much greater. Subjects must retain both the consonant and the vowel, and with nonsense syllables this cannot be facilitated by semantic information. The increased memory load is reflected in the lower accuracy for the mixed vowel condition.

![Figure 6. Experiment 2: The mean number of correct responses (total syllable) reported plotted for each reading group.](image)

Good readers show a greater improvement on the easier memory task (same vowel set) than do the poor readers, $F(1,28) = 8.59, p = .007$. The particular pattern of errors by good and poor readers for vowels and consonants will be discussed below in the error analysis section. Further, the results of the same vowel and mixed vowel sets in relation to other studies investigating the effects of rhyme on recall will be addressed in the conclusion.

In sum, the results of the correct response analyses show that good readers have performed significantly better on both conditions (same and
mixed-vowel) and for both scoring techniques (consonant alone and whole syllable).

Error analysis. Turning to analyses of the types of errors, we found, as in Experiment 1, that the majority of errors consisted of misorderings of the items in the string, rather than substitutions of new items or omissions. This effect was significant both for the same vowel condition, $F(1,28) = 135.11, p < .001$, and the mixed vowel condition, $F(1,28) = 196.08, p < .001$.

However, in the mixed vowel set, in which we can examine vowel errors, the errors for consonants and vowels differed somewhat. As noted, the reading groups differed significantly on the consonant errors, $F(1,28) = 5.64, p = .025$, but the difference was not obtained for vowel errors, $F(1,28) = 2.51, p = .124$. Although both groups produced many errors on the vowels, error rate did not distinguish the groups.

Table 3 displays the ways in which the consonants and vowels vary as to error type. First, as stated earlier, it can be seen that for the consonants, very few errors consisted of substitutions or omissions. With such a limited data set, this is as would be expected. For the vowels a larger set of stimuli was possible in any particular string, and a fair number of substitution errors occurred. Second, few of the errors for either reading group consisted of entire syllable misorderings, and no group difference was observed for this error type, $F(1,28) = 1.90, p = .179$. Third, the majority of errors consist of transpositions of the available consonants and vowels, which create new syllables. The significant difference between good and poor readers arises from the greater frequency of transposition errors for the poor readers.
Let us next look, as in Experiment 1, at the effects of adjacency and phonological similarity on the occurrence of consonant errors. It is clear from Figure 7 that there is a pronounced effect of adjacency on errors in both vowel conditions. For both good and poor readers, transpositions more often involved consonants from adjacent syllables than from nonadjacent stimuli (same vowel set, $F(1,28) = 104.72, p < .001$; mixed vowel set, $F(1,28) = 41.71, p < .001$). Further, there were also significant effects of phonetic feature similarity on the incidence of transposition errors (same vowel set, $F(2,27) = 6.61, p = .005$; mixed vowel set, $F(2,27) = 5.33, p = .011$). Order errors were thus more likely to occur between stimuli that shared phonetic information. In this experiment, in contrast to the first experiment, the effects of phonetic similarity were evident both for the adjacent errors and for the nonadjacent errors. Therefore, in Figure 8, the data for similarity effects are combined for these two error types. The reader will recall that the effects of similarity had been more pronounced in the first experiment for the nonadjacent errors. It is not clear whether this difference between Experiment 1 and Experiment 2 may indicate a developmental increase in sensitivity to phonological factors relative to adjacency effects, or whether it may be related to the particular stimuli used in these memory tasks.

In any case, to summarize, although the poor readers made more errors than good readers, the majority of errors for both consisted of reorderings of the phonetic information in the string. These recombinations showed strong influences of adjacency and phonetic similarity reflecting, we presume, the underlying processing strategies. The kinds of errors suggest that the inferior performance of poor readers on these short-term memory tasks is not the consequence of a different coding strategy, but rather of a lesser degree of skill with a phonetic strategy.

Conclusion

Our goal was to conduct studies that would allow us to determine the coding processes of good readers and poor readers on short-term memory tasks. Previous work (Brady et al., 1983) had provided preliminary evidence that poor readers, like good readers, use a phonetic code in STM. In the present experiments this question was directly evaluated using nonsense strings in which the phonetic similarity of the items was controlled.

Good and poor readers from the second grade (Experiment 1) and from the third grade (Experiment 2) were tested in experiments with differing sets of consonant/vowel syllables. The results of the two experiments were congruent: The majority of consonant errors consisted of transpositions of one item from the sequence for another, with significant effects of phonetic similarity. This pattern held for both good readers and poor readers. The two groups differed, however, in the occurrence of consonant transposition errors, which were significantly more frequent for the children with reading problems. Both reading groups also showed significant effects of adjacency: order confusions for all stimuli were more likely to occur between adjacent items than between nonadjacent items. This pattern was produced by good readers and poor readers and probably reflects the demands of a serial order task.

In the second experiment a mixed-vowel condition was added that allowed an examination of vowel errors. While both good and poor readers produced a fair number of errors for vowels, the error rate did not distinguish the reading groups.
ADJACENCY

Same Vowel

Mixed Vowel

Figure 7. Experiment 2: The mean number of times the error consisted of an item from a nonadjacent or an adjacent position.

SIMILARITY

Same Vowel

Mixed Vowel

The number of shared features for the reported item and the target

Figure 8. Experiment 2: Analysis of feature similarity effects.
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A comment is in order about the relative difficulty of the same vowel (rhyming) and mixed vowel (nonrhyming) sets. Our results are seemingly at odds with what is generally found. As mentioned in the introduction, adult subjects and good readers usually have better recall for non-rhyming items than for lists of rhyming stimuli (e.g., Baddeley, 1966; Shankweiler et al., 1979). The greater confusion in recall when the items are phonetically similar has been taken as reflecting the coding processes in STM. However, these findings have been obtained for longer sequences than were used in the present experiment. The effects of rhyme may well depend on how taxed the system is (a similar idea has been expressed by Hall, Wilson, Humphreys, Tinzmann, & Bowyer, 1983). The everyday experience of rhyme facilitating recall may be related to this. In the present task, sequences were deliberately kept short so as to optimize the subject's ability to recall the correct number of stimuli. We thought this would facilitate the examination of order errors and transposition errors in the reported items. For longer strings subjects increasingly fail to recall the entire sequence. In that case, partial report by the subject (e.g., giving 4 out of 7 stimuli) permits a less structured analysis of errors.

That rhyme effects are tied to task factors has also been suggested by results obtained for adults (see Watkins, Watkins, & Crowder, 1974). In a paradigm similar to the present one using short strings of nonsense syllables, Ellis (1980) did not find significant differences in the error rates for an all-same vowel condition and for an all-different vowel condition (though with other conditions there was a significant effect of vowel environment on error rate). Thus, the particular type of STM task used in the present experiment has not been found to produce the standard rhyme effect with normal adults.

Analyses of previous STM studies with children varying in reading ability shows that the levels of recall on STM tasks have consistently distinguished reading groups. However, the effects of rhyme have proved to be somewhat labile. As for adults, task factors appear to influence the relative difficulty of rhyming strings. Hanson, Liberman, and Shankweiler (1984) also found repeated rhyming strings to be easier for subjects. In their task they also used short sequences (4 items) with the same stimuli repeated on each trial in varying order. In addition, the "rhyme effect" appears to be sensitive to subject characteristics (Hall et al., 1983) and to age effects (Olson, Davidson, Kliegl, & Davies, 1984). It is evident that additional work is necessary to understand the basis of the traditional rhyme effect in STM.

In the present study, we are asking a different question: can we find out whether good and poor readers employ different strategies in STM? What is critical is not so much the direction of the effect of rhyme but whether poor readers are susceptible to effects of phonetic similarity. To summarize our findings on that question, error analyses revealed that both good and poor readers show effects of phonetic similarity from which we infer that both groups use a phonetic coding strategy. The inferior performance of the poor readers arose from a higher incidence of errors involving transpositions of consonants sharing phonetic features. The shared features can be presumed to place demands on phonetic coding skills, thus these results suggest that the STM deficit associated with poor readers is related in some degree to greater difficulty in establishing or maintaining a phonetic code.
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The factors of phonetic similarity and adjacency have been noted as important aspects of STM processing for adults as well. Several authors have noted that errors in recall by adults show effects of feature similarity (Cole, Haber, & Sales, 1968; Cole, Sales, & Haber, 1969; Hintzman, 1967; Wickelgren, 1966). Further, Ellis (1980) specifically documented effects of phonetic parameters on the occurrence of transposition errors by adults on tasks similar to those in the present experiments. Hitch (1974) and Ryan (1969) also reported a strong effect of adjacency in the recall errors of adults.

Thus the same processing strategies appear to be at work for adults, children who are good readers, and children who are poor readers. Yet a difference exists between groups in recall level, with adults performing better than children, and good readers recalling more than poor readers. We are suggesting that the STM deficit of poor readers is related to less efficient processing of phonetic information by those children, perhaps reflecting a maturational lag (Mann & Liberman, 1984; Satz & Sparrow, 1970). In a developmental study, Olson et al. (1984) reported the same improvements in recall and sensitivity to phonetic factors in poor readers as in good readers, but at an older age.

Case, Kurland, and Goldberg (1982) have offered an account of why younger children in general perform less well that may also apply to poor readers. These authors argue that as a child gets older, basic encoding and retrieval operations in STM become more efficient, resulting in more functional storage space (and in a concomitant increase in short-term memory capacity). In support of this interpretation, they report a linear relationship between increases in memory span and increases in speed of word repetition for normal children 3 to 6 years old. Their position is buttressed by an additional experiment in which adults were forced to count in an unfamiliar language. The speed of counting for the adults was now equal to the rate of six-year-olds, and their memory span correspondingly dropped.

It may be worth noting that individual differences in memory span are found throughout the lifespan. Furthermore, there are some indications that phonological skills also vary for adults and that these two findings may be related. For example, Baddeley, Thomson, and Buchanan (1975) found that adults' memory span could be predicted on the basis of the number of words that the subject could read in approximately 2 seconds.

To summarize, the present work indicated that children who are poor readers are using the same phonetic processes in STM as are good readers or adults, but less efficiently. We would like to explore further the relationship of phonetic processing skills to short-term memory to determine whether that relationship can account for the developmental changes in short-term memory that have been observed and for the memory differences for children differing in reading ability.

References


Footnotes

1In the remainder of the analyses for Experiments 1 and 2, the data were likewise reanalyzed controlling for age and IQ. In no case was the significance of the differences between reading groups reduced when age and IQ were controlled.

2The criteria for inclusion were adjusted for children a year older. Subjects were selected whose ages fell within the range of 100 to 112 months.