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The use of phonological information by good and poor readers in memory and reading tasks

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There has been a recent debate about the utilization of phonological information by poor readers in both working memory and reading tasks. The purpose of the first experiment in this study was to examine whether the absence of phonological similarity effects in working memory reported in previous studies was due to inappropriate levels of task difficulty. Poor readers and their reading age controls were found to show a normal effect when the memory task was at an appropriate level of difficulty, but no effect when a large number of items had to be recalled. However, in a recognition memory task, the poor readers chose orthographically similar pairs, whereas the reading-age and chronological age controls chose phonologically similar pairs. The purpose of a final experiment was to determine whether or not the good and poor readers could be differentiated in terms of their reading strategies; both groups showed regularity effects in a naming task and pseudohomophone effects in a lexical decision task. However, although poor readers could read three-letter nonwords as well as their controls, they were significantly impaired in reading more complex one-syllable nonwords. It was concluded that poor readers may have a phonological dysfunction in some aspects of reading that is unrelated to whether or not they show phonological similarity effects in working memory. Impaired segmentation skills may underly their difficulties in both reading and nonreading tasks.

Many studies have been carried out in order to examine the idea that poor readers are deficient in utilizing phonological information in both memory and reading tasks. In a review of the literature, Vellutino (1979) has concluded that poor readers are deficient in their use of verbal or phonological information in both short- and long-term memory tasks. Similarly, Frith (1985) has concluded that poor readers suffer primarily from a phonological dysfunction in reading.

In the memory literature, a number of studies have shown that poor readers use phonological information less effectively than good readers. Shankweiler, Liberman, Mark, Fowler, and Fischer (1979) demonstrated that 8-year-old poor readers, in a serial order recall task involving memory of letter strings, showed smaller effects of phonological similarity than did chronological age controls. They concluded that poor readers have poorer access to a phonetic code or access to a degraded phonetic representation. A number of other studies have since confirmed these findings. Mann, Liberman, and Shankweiler (1980) showed similar effects when words and sentences were presented for recall, and Siegel and Linder (1984) replicated the Shankweiler et al. findings on 7- to 8-year-old poor readers.

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Johnston (1982), however, found normal effects of phonological similarity in 9-, 12-, and 14-year-old poor readers, and cautiously concluded that such reduced effects must be restricted to young poor readers aged 8 and below. Hall, Wilson, Humphreys, Tinzmann, and Bowyer (1983) subsequently demonstrated normal phonological similarity effects in 8-year-old poor readers. Their study, however, was problematic in the sense that their poor readers did not show the reduced memory span compared to age-matched controls that so many studies report, and therefore did not manifest the inefficient memory processes that Shankweiler et al. (1979) were trying to explicate. Hall et al. (1983), however, did find that poor readers of generally low ability exhibited normal effects of phonological similarity when asked to recall four items, but no effect when asked to recall five items. This raised the question as to whether the earlier findings of reduced phonological similarity effects were a product of inappropriate levels of task difficulty. Johnston, Rugg, and Scott (1987b) determined the memory span of good and poor readers individually, in order to administer an immediate memory task at an appropriate level of difficulty for each child. Poor readers were found to have shorter memory spans than their age-matched controls, and both the 8-year-old and 11-year-old poor readers showed normal effects of phonological similarity when task difficulty was controlled for, as did the good readers.

However, findings on differences in the use of phonological information by good and poor readers in recognition-memory and cued-recall tasks have been more consistent. Mark, Shankweiler, Liberman, and Fowler (1977) found, in a recognition memory task, that only good readers made significantly more false positive responses to rhyming distractors. In a similar study, Byrne and Shea (1979) found, in addition to replicating these results, that poor readers tended to make more false positive responses to semantic distractors. Such findings may, however, be age specific, for Olson, Davidson, Kliegl, and Davies (1984) were only able to replicate them with 8-year-olds. Rack (1985) investigated memory coding in 12- to 13-year-old poor readers, using a cued-recall task. Subjects initially judged whether pairs of words rhymed; subsequently, one item of each pair was presented to the child as a cue to recall the other item. Although the poor readers and reading-age controls were equally accurate at judging rhyme in the first task, group differences were found in the cued-recall task. The reading-age controls were better at recalling pairs if the cue rhymed with the target than if it did not; no such difference was found with the poor readers. The latter group also showed a greater influence of orthography in this task.

Studies of reading strategies in poor readers have shown a similarly mixed picture. Most studies in this area take as their basis a dual route model of reading (Coltheart, 1978). This model proposes that access to the meaning or pronunciation of words can be achieved either directly, through visual access, or indirectly, through grapheme-to-phoneme conversion rules. According to this model, irregular words such as *yacht* may only be read by the direct route, whereas regular words such as *best* can be read by either route. Thus slower and less accurate pronunciation of irregular than of regular words indicates a phonological approach to reading. Recent research suggests that in skilled adult readers, such effects are probably limited to low frequency words that are both orthographically and phonologically irregular, such as *aisle* (Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Similarly, it has been found that skilled adults are neither slower nor less accurate in making lexical decisions with respect to pseudohomophones versus nonwords, as long as these items are closely matched in orthographic similarity to real words (Martin, 1982; Taft, 1982). There seems to be no influence of phonological information in the performance of this task. It would seem for the most part that skilled adults read by utilizing the direct visual route.

A study by Waters, Seidenberg, and Bruck (1984) showed that poor readers were able to make use of the indirect or phonological route. The children in this study were found to read irregular words more slowly and less accurately than they read regular words. Furthermore, the chronological-age controls also showed this effect, indicating that the utilization of phonological information is a normal stage in reading development. Other studies, however, have suggested that poor readers are impaired in using a phonological approach to reading. Thus Snowling (1981) and Baddeley, Ellis, Miles, and Lewis (1982) found poor readers to be less accurate at pronouncing nonwords than were reading-age controls. Still other studies have failed to find impaired nonword naming in poor readers (e.g., Beech & Harding, 1984; Johnston, Rugg, & Scott, 1987a); Treiman & Hirsh-Pasek, 1985).

Our purpose in the present study was to investigate to what extent poor readers show evidence of impaired phonological processing in both memory and reading tasks. One possible explanation of the contradictory findings in this area is that they are due to sample differences. Thus some groups of poor readers may not use phonological information effectively in working memory and may also have difficulty in using spelling-to-sound rules when reading, whereas other groups may not suffer from these particular types of impairment. However, there is a possibility that the studies showing reduced phonological similarity effects in poor readers used tasks that were too difficult for the poor readers, as Hall et al. (1983) suggested. Experiment 1 of the present study was designed to examine this possibility. Eight-year-old poor readers and their reading-age controls carried out phonological similarity tasks at (1) an appropriate level of task difficulty, and (2) a level exceeding the limit of their memory spans. Experiments 2 and 3 examined the issue of whether these poor readers would show normal utilization of phonological information in a recognition memory task similar to Rack's (1985). Finally, in Experiment 4 the same children carried out various reading tasks so that we might assess whether they exhibited a phonological dysfunction in reading.

EXPERIMENT 1

Method

Subjects

Twenty poor readers of mean chronological age 8.5 years were selected on the basis that their reading ages must be at least 1 year behind chronological age, according to the Word Recognition Test of the British Ability Scales (Elliott, Murray, & Pearson, 1977). Their IQ on the WISC-R (Wechsler, 1974) short form (Maxwell, 1959) had to be at least 90; this test includes the Similarities, Vocabulary, Object Assembly, and Block Design subtests. Mean reading age was 7.0 years and mean IQ was 103.65.

Twenty younger normal readers were selected as reading-age controls. Their mean chronological age was 7.16 years; mean reading age was 7.18 years, and mean IQ was 107.70 (see Table 1).

Procedure

The following procedure for the easy condition is identical to that of Johnston et al. (1987b), except that in the present study the subjects wrote down the items they recalled, whereas in the earlier study the responses were noted by the experimenter. The letters used in Experiment 1 (*b, c, d, g, h, k, l, p, q, r, s, t, v, w*) were presented singly in lower case, on the monitor of a microcomputer; the subjects were asked to read them out loud so that the experimenter could check whether they were able to recognize the letters. No child had to be excluded on these grounds.

Practice

Four practice sets were used, consisting of three letters in each string; none of these items was used in the main experiment. The letters appeared in sequential order in the center of the screen, remaining there for 1 sec. A 1-sec gap separated the items. At the offset of the final letter in a string, a flashing cursor appeared in

Table 1
Experiments 1, 2, 3, and 4 Mean Reading Age, Chronological Age, and IQ

	Reading Age		Chronological Age		IQ	
	M	*SD*	*M*	*SD*	*M*	*SD*
Poor readers	7.00	.31	8.50	.39	103.65	9.29
Reading-age controls	7.16	.20	7.18	.27	107.70	14.90
Chronological age controls	8.45	.49	8.32	.47	106.40	.63

the same location to indicate recall. The subjects were provided with answer booklets for writing down the items; they were requested to write down the items in the order that they had seen them in, leaving a space for any item they could not remember.

Determination of Memory Span

Each subject's memory span was then determined on the basis of performance on the phonologically dissimilar letters (i.e., *h, k, l, g, r, s, w*). An ascending staircase procedure was used, starting with string lengths of two items. Correct recall of a string length led to the number of items[1] being incremented by one for the next trial. Memory span was set at one item less than the length at which two consecutive errors had occurred.

Experimental Task

Each child received alternating trials of phonologically similar and dissimilar letters from the sets *b, c, d, g, p, t, v* and *h, k, l, g, r, s, w* respectively. There were seven trials for each set per condition, with each letter appearing exactly once in each serial position. The subjects wrote down the items in booklets, as for the practice trials. Two conditions were used: (1) an easy condition, with string length appropriate for each subject's memory span; (2) a hard condition, with each child receiving string lengths three items longer than memory span allowed. The order of presentation was counterbalanced so that half the subjects received the easy task first, and half received the hard task first.

Results

Memory Span

A one-way analysis of variance was carried out on the span scores of the two groups of children. The reading-age controls had significantly better memory spans than the poor readers [$F(1,38) = 6.90, p < .02$].

Effects of Phonological Similarity

For each subject, the proportion of letters recalled correctly in the appropriate serial position was computed for both phonologically similar and dissimilar items (see Table 2). A three-way analysis of variance was carried out on these data, there being two within-subjects factors: phonological similarity (similar and dissimilar sounding items) and conditions (easy and hard). There was one between-subjects factor: groups (poor readers and reading-age controls).

No significant difference was found between groups ($F < 1$). Performance was better in the easy condition [$F(1,38) = 213.36, p < .0001$], and dissimilar sounding items were better recalled than similar sounding ones [$F(1,38) = 38.20, p < .0001$]. However, these effects were modified by an interaction between conditions and phonological similarity [$F(1,38) = 29.05, p < .0001$]. Newman-Keuls tests showed that in the easy version of the task, dissimilar sounding items were recalled better than similar sounding ones. However, in the hard version of the task, recall did not differ for the two types of items.

Discussion

These results confirm the findings of Hall et al. (1983) and Johnston et al. (1987b) that 8-year-old poor readers can show normal effects of phonological similarity. However, it was also shown that when task difficulty is increased, neither poor readers nor their reading age controls show effects of phonological similarity.

EXPERIMENT 2

The purpose of Experiment 2 was to see whether these poor readers would show memory coding similar to that of reading-age controls in a recognition memory task, in which items previously presented in a rhyme judgment task had to be identified.

Method

Subjects

The subjects were the same as in Experiment 1, which was administered to the children before Experiment 2.

Materials: Rhyme Judgment Task

The stimuli consisted of 64 word pairs, categorized into four types, orthographic and phonological similarity being varied orthogonally (see Appendix A). The four types were as follows:

Type 1. These were orthographically dissimilar rhyming word pairs, such as *rude-food* [mean frequency = 205 (*SD* = 341) and 201 (*SD* = 297), respectively], in accordance with Carroll, Davies, & Richman's (1971) Grade 3 norms.

Type 2. These were orthographically similar rhyming word pairs, such as *town-down* [mean frequency = 275 (*SD* = 361) and 162 (*SD* = 369), respectively].

Table 2
Experiment 1: Mean Percent Correct Recall of Phonologically Similar and Dissimilar Letters

	Poor Readers		Reading-Age Controls	
	M	*SD*	*M*	*SD*
Mean Span	3.55	.51	3.90	.30
Easy Task				
Similar	50.00	17.20	47.65	13.01
Dissimilar	69.65	18.71	68.30	16.39
Hard Task				
Mean String Length	6.55	.51	6.90	.30
Similar	24.70	6.13	27.55	7.61
Dissimilar	27.35	9.51	28.90	11.49

Type 3. These were orthographically dissimilar nonrhyming word pairs, such as *boil-safe* [mean frequency = 247 (*SD* = 214) and 205 (*SD* = 219), respectively).

Type 4. These were orthographically similar nonrhyming word pairs, such as *lost-post* [mean frequency = 146 (*SD* = 209) and 175 (*SD* = 298), respectively].

Materials: Recognition Memory Task

Condition A: recognition memory for orthographically similar pairs. Twelve pairs of words were taken from the Type 4 pairs in the rhyme judgment task, these items being orthographically similar but nonrhyming; they constituted the cue and target items. Three other items were presented as distractors. One of them was a foil word that rhymed with the cue, yet was orthographically dissimilar; the other two distractors were unrelated. Thus, for example, a child might be shown *post* as the cue, *lost* as the target, and *toast* as the foil; *fail* and *each* were the unrelated distractors (see Appendix B).

Condition B: recognition memory for rhyming pairs. Seven pairs of words were selected from the Type 1 list, these pairs being orthographically dissimilar but rhyming. The first item constituted the cue, and the second item constituted the target. Three other items formed the distractors. Of these, one was a foil item, orthographically similar to the cue, but not rhyming with it. Thus, for example, a child might be shown *food* as the cue, *rude* as the target, and *hood* as the foil; *puff* and *torn* were the unrelated distractors (see Appendix B).

Procedure

Rhyme judgment task. The word pairs were randomized and presented successively in lower case on the monitor of a microcomputer. The first item of each pair remained on the screen for 1 sec, the screen being blank for 1 sec until the appearance of the second word; this item remained on the screen until the subject made a response. As each word appeared, the child pronounced it; if the child got the word wrong, it was pronounced for him. This ensured that the children always generated the phonological code, or were made aware of it, prior to making a rhyme judgment. As the children were closely matched on oral word-recognition ability (see above on Subjects, Experiment 1), it was not felt necessary to record accuracy of pronunciation. The teachers of the children concerned were consulted, to make sure that the items were familiar to the children in both groups.

Recognition memory task. Immediately after the rhyme judgment task, the children were asked to carry out the recognition memory task; they were not given prior warning of the second phase of the experiment. The cue item was read aloud by the experimenter as it was shown to each child, and placed faceup on the desk. The other four items were randomized, shown to the child, and read out loud one-by-one by the experimenter. Each item was placed faceup on top of the preceding card. The children were told not to make a choice until all the cards had been presented. If they were uncertain about the choice, they were permitted to sort through the set of cards before making a decision. All 19 sets of cards were randomized before testing, so that the conditions were not presented in blocks. This design was adopted in order to discourage the children from developing response biases in their choices. Furthermore, the children were not permitted to make their choices while the cards were exposed on the table.

Results

Rhyme Judgment Task

The mean number of items correct was calculated for the four types of word pairs. A three-way analysis of variance was carried out on these data. There was one between-subjects factor: groups (poor readers and reading-age controls). There were two within-subjects factors: rhyme (rhyming vs. nonrhyming word pairs) and similarity (orthographically similar vs. orthographically dissimilar word pairs). Table 3 shows the means and standard deviations.

The poor readers were worse overall at rhyme judgment than were the reading-age controls [$F(1,38) = 27.60$, $p < .0001$]. For all the children, the responses to dissimilar items were more accurate than the responses to similar ones [$F(1,38) = 40.32$, $p < .0001$], but there was no main effect of rhyme ($F < 1$). However, rhyme and similarity also interacted [$F(1,38) = 109.92$, $p < .0001$]. Newman-Keuls tests showed that the responses to Type 4 pairs (e.g., *lost-post*) were less accurate than the responses to nonrhyming controls (i.e., Type 3 pairs, such as *boil-safe*), and that the responses to Type 1 pairs (e.g., *rude-food*) were less accurate than the responses to rhyming controls (i.e., Type 2 pairs, such as *town-down*). The interaction between group and rhyme was nonsignificant [$F(1,38) = 2.03$, $p > .05$], and $F < 1$ for all other effects.

Recognition Memory Task

The mean percentage of correct choices was calculated for each group of subjects, as was done with their responses to the foils and the two distractors. The means and standard deviations are to be found in Table 4.

A three-way analysis of variance was carried out on correct and foil choices. There was one between-subjects factor, groups (poor readers and reading-age controls); there were two within-subjects factors, response category (correct or foil choice) and conditions (A and B).

There was a marginally nonsignificant difference between the groups [$F(1,38) = 3.40$, $p < .07$], favoring the reading-age controls. There were significant main effects of conditions [$F(1,38) = 12.33$, $p < .002$] and response categories [$F(1,38) = 45.86$, $p < .0001$]; but

Table 3
Experiments 2 and 3: Mean Accuracy Scores (out of 16) on Rhyme Judgment Task

	Type 1 (*food-rude*)		Type 2 (*town-down*)		Type 3 (*boil-safe*)		Type 4 (*post-lost*)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Poor readers	9.00	2.90	11.15	2.78	13.15	2.06	7.70	3.23
Reading-age controls	12.05	2.14	13.90	1.83	14.90	1.02	9.0	3.23
8-year-old normal readers	13.05	1.61	14.70	1.42	15.3	.80	8.95	3.38

Table 4
Experiments 2 and 3 Mean Percent Correct Recall on Recognition Memory Task

	Poor Readers		Reading-Age Controls		Chronological-Age Controls	
	M	*SD*	*M*	*SD*	*M*	*SD*
	Condition A (*post-lost*)					
Correct (e.g., *lost*)	70.0	13.6	46.2	32.2	45.8	21.7
Foil (e.g., *toast*)	12.9	5.7	42.0	27.0	42.5	24.2
Distractors (e.g., *each*)	14.6	9.3	11.8	13.1	6.3	8.5
Nonresponse	2.5	5.4	0.0	.0	5.4	13.9
	Condition B (*food-rude*)					
Correct (e.g., *rude*)	37.8	24.2	80.0	14.2	74.3	13.6
Foil (e.g., *hood*)	52.9	36.7	15.0	10.8	19.3	12.5
Distractors (e.g., *torn*)	6.4	8.6	5.0	8.4	2.9	5.9
Nonresponse	2.9	5.9	0.0	.0	3.6	7.9

these were modified by a significant three-way interaction between groups, response categories, and conditions [$F(1,38) = 47.15$, $p < .00001$]. Newman-Keuls tests showed that the reading-age controls made more correct responses to Condition B pairs (e.g., *rude-food*) than did the poor readers, but that the poor readers made more correct responses to Condition A pairs (e.g., *lost-post*) than did the controls. As far as foil choices were concerned, the poor readers were more likely to choose orthographically similar foils on Condition B pairs than were the controls, who in turn chose more rhyming foils on Condition A pairs than did the poor readers.

EXPERIMENT 3

Although the poor readers in Experiment 2 performed very differently than the reading-age controls did, the question arises as to whether these memory coding differences were related to their reading difficulties or were normal for their chronological age. The relative advantage for orthographically similar pairs of words in recognition memory may develop with age, and may not reflect differences in cognitive functioning between poor readers and age-matched controls. Thus Experiment 3 was carried out in order to determine whether 8-year-old normal readers would show better recall of orthographically dissimilar rhyming word pairs, like the 7-year-old normal readers, or better recall of orthographically similar nonrhyming pairs, like the 8-year-old poor readers.

Method

Subjects

Twenty normal readers were selected. Their mean chronological age was 8.32 years, their mean reading age on the British Ability Scales Word Recognition Test was 8.45 years, and their mean IQ (on the WISC-R short form) was 106.4 (see Table 1).

Materials

These were the same stimuli as were used in Experiment 2.

Procedure

Rhyme judgment task. This was similar to the rhyme judgment task in Experiment 2, except that the children were not asked to pronounce the word pairs out loud prior to making their rhyme judgments.

Recognition memory. This was carried out according to the procedures followed in Experiment 2.

Results

Rhyme Judgment Task

A two-way analysis of variance was carried out on these data. There were two within-subjects factors, rhyme (rhyming and nonrhyming word pairs) and similarity (orthographically dissimilar and orthographically similar word pairs).

There were main effects of rhyme [$F(1,19) = 11.44$, $p < .003$] and similarity [$F(1,19) = 42.35$, $p < .00001$]. However, these effects were modified by an interaction between rhyme and similarity [$F(1,19) = 70.70$, $p < .0001$]. Newman-Keuls tests showed that the responses to Type 4 pairs (e.g., *lost-post*) were less accurate than the responses to Type 3 pairs (e.g., *boil-safe*), and that the responses to Type 1 pairs (e.g., *rude-food*) were less accurate than the responses to Type 2 pairs (e.g., *town-down*). See Table 3 for means and standard deviations.

Recognition Memory Task

A two-way analysis of variance was carried out, the two within-subjects variables being response category (correct and foil choice) and conditions (Condition A and Condition B). See Table 4 for means and standard deviations. There was a main effect of conditions [$F(1,19) = 5.99$, $p < .03$] and of response choice [$F(1,19) = 25.82$, $p < .0001$]. However, these were modified by an interaction between conditions and response choice [$F(1,19) = 25.82$, $p < .0001$]. Newman-Keuls tests showed that the children made more correct choices to Condition B pairs (e.g., *food-rude*) than to Condition A pairs (e.g., *post-lost*). Similarly, with foil choices, they chose more rhyming foils in Condition A than orthographically similar foils in Condition B. Thus their performance was very similar to that of the younger normal readers in Experiment 2.

EXPERIMENT 4

Experiment 4 comprised four tasks, which were carried out after Experiments 1 and 2 on the same subjects.

Method

Materials

Regularity task. The stimuli were 60 monosyllabic words, divided into four classes: (1) high frequency regular words; (2) low frequency regular words; (3) high frequency irregular words; (4) low frequency irregular words. Regularity was determined according to the criteria set down by Venezky (1970). On the basis of the Grade 3 norms from Carroll et al. (1971) the mean word frequencies were determined to be as follows: high frequency regular words, mean = 324.5 (*SD* = 216.6); low frequency regular words, mean = 27.6 (*SD* = 24.08); high frequency irregular words, mean = 329.0 (*SD* = 316.2); low frequency irregular words, mean 29.1 (*SD* = 24.7). These items are listed in Appendix C.

Pseudohomophone task. These items, which were constructed by Johnston, Rugg, and Scott (in press), consisted of 24 pseudohomophones, 24 nonwords, and 48 filler words (to equate the number of "yes" and "no" responses; see Appendix D). The pseudohomophones and nonwords were derived according to Taft's (1982) criteria. Two words that were visually similar yet had differing pronunciations of their vowel sounds were selected—for example, *bear* and *near*. The vowel digraph *ea* was replaced with the digraph *ai* in both words, producing the pseudohomophone *bair* and the nonword *nair*. For each of these items, a control word was selected, with length and word frequency similar to those of the original word (according to Grade 3 norms; see Carroll et al.). The mean word frequency for the words matched to the pseudohomophones was 509 (*SD* = 1455), and for those matched to the nonwords, 638 (*SD* = 1191). Each item was presented in lowercase print on an index card.

Pronunciation of pseudohomophones and nonwords. These were the 24 pseudohomophones and 24 nonwords used in the pseudohomophone task above. The pronunciation task was always carried out before the lexical decision task.

Pronunciation of easy nonwords. These were a set of 20 three-letter nonwords, which were nonhomophonic with words. See Appendix E for these items.

Procedure

Regularity task. The items were randomized and presented singly in lowercase on index cards. The children were asked to read the items out loud at their own pace, and the experimenter recorded each child's response.

Pseudohomophone task. The children were told that the cards contained a mixture of real words and "made-up" words. They were asked to put the real words into one pile and the made-up ones into another pile, as quickly and as carefully as possible. Before being given the entire pack, which consisted of a randomized ordering of the words and nonwords, the children were given some practice at the task. They received a set of eight cards: on each of four cards, a word was written; two cards each contained a nonword, and two each contained a pseudohomophone. Each child was then asked to place the cards on the table in separate piles. When the child misclassified a pseudohomophone as a word, this was discussed. It was pointed out that just because the pseudohomophone sounded like a real word it was not necessarily a real word. The spelling of the pseudohomophones, however, was not commented upon. Other misclassifications that occurred were also discussed, but because these were rare, in general it was only the misclassifications of pseudohomophones that had to be pointed out.

Each child received the entire set of 96 items in a different random order. This was accomplished by shuffling the cards before each testing session. No feedback was given as to the correctness of the classifications during the experimental trials.

Pronunciation of pseudohomophones and nonwords. The nonwords were printed in lowercase on index cards, one item per card. The items were randomized for each child by shuffling prior to testing. The children were asked to read the items out loud at their own pace, and they were told that all the items were "made-up" words.

Pronunciation of easy nonwords. The nonwords were printed in lowercase on index cards, one item per card. The items were randomized for each child by shuffling prior to testing. The children were asked to read the items out loud at their own pace, and they were told that all the items were "made-up" words.

RESULTS

Regularity Task

These data were expressed as the percent correct within each category. A three-way repeated measures analysis of variance was then carried out. See Table 5 for the means and standard deviations. There was one between-subjects factor, groups (poor readers and reading-age controls), and there were two within-subjects factors, regularity (regular and irregular words) and frequency (high and low frequency words). There was no main effect of groups ($F < 1$). However, more correct responses occurred with respect to regular than to irregular words [$F(1,38) = 67.11, p < .0001$], and with respect to high rather than to low frequency words [$F(1,38) = 122.76, p < .0001$]. There was an interaction between regularity and frequency [$F(1,38) = 7.31$, $p < .01$], and Newman-Keuls tests showed all pairwise comparisons to be significant. The interaction was most probably due to a larger frequency effect on irregular than on regular words. No other effects were significant ($F < 1$ in all cases). Thus, poor readers and reading-age controls showed regularity effects of similar magnitude.

Pseudohomophone Task

The data were expressed as the percent correct for pseudohomophones and nonwords. A two-way analysis of variance with repeated measures was then carried out

Table 5
Experiment 4: Mean Percent Correct on Regularity Task

	Regular Words				Irregular Words			
	High Frequency		Low Frequency		High Frequency		Low Frequency	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Poor readers	67.6	17.6	51.3	18.3	56.7	20.1	29.3	13.6
Reading-age controls	67.7	14.4	51.3	18.7	57.7	16.4	32.2	9.2

Table 6
Experiment 4: Mean Percent Correct on Lexical Decision Task

	Pseudohomophones		Nonwords	
	M	*SD*	*M*	*SD*
Poor readers	49.0	18.0	70.2	14.7
Reading-age controls	49.8	18.2	72.3	15.6

on these data. There was one between-subjects factor, groups (poor readers and reading-age controls), and there was one within-subjects factor, nonword type (pseudohomophones and nonwords). See Table 6 for the means and standard deviations. No between-groups difference was found ($F < 1$). However, there was a main effect of type of nonword [$F(1,38) = 69.85, p < .001$], pseudohomophones being significantly more likely to be misclassified as words than nonwords. The lack of a group × type of nonword interaction ($F < 1$) indicates that both groups showed a pseudohomophone effect to the same degree.

Pronunciation of Pseudohomophones and Nonwords

The subjects' responses were expressed as percent correct within each category, and a two-way repeated measures analysis of variance was carried out on these data. There was one between-subjects factor, groups (poor readers and reading-age controls) and one within-subjects factor, nonword type (pseudohomophones and nonwords). The means and standard deviations are shown in Table 7. A number of significant main effects were found. There was a main effect of groups [$F(1,38) = 5.42, p < .03$], the reading-age controls being more accurate. There was also a main effect of nonword type [$F(1,38) = 165.24$, $p < .0001$], pseudohomophones being read more accurately than nonwords. There was no interaction between groups and type of nonword ($F < 1$). Thus the poor readers were found to be impaired in naming both pseudohomophones and nonwords in this task.

Pronunciation of Easy Nonwords

The data were expressed as percent correct, and a one-way analysis of variance was carried out (see Table 7 for the means and standard deviations). There was one between-subjects factor, groups (poor readers and reading-age controls). No between-groups difference was found ($F < 1$).

GENERAL DISCUSSION

Experiment 1 showed that poor readers do exhibit normal effects of phonological similarity in working memory tasks if the level of difficulty is appropriate to their memory spans. However, if the task is made very difficult, they no longer show superior recall of dissimilar sounding items. Thus, it is possible for such effects to be abolished in children under these circumstances, as Hall et al. (1983) suggested. However, it is necessary to show that the studies demonstrating reduced phonological similarity effects did indeed involve high levels of task difficulty. In the present study, recall levels in the poor readers were reduced to about 25% in the hard condition. The overall recall exhibited by Shankweiler et al.'s (1979) poor readers was also fairly low: 39.5% for dissimilar items, and 29% for similar items with visual, simultaneous presentation. Similarly, Siegel and Linder (1984) reported that their poor readers recalled around 34% of dissimilar, and 35% of similar, items. Thus in all of these studies that show reduced effects, there is evidence that the recall task was set at a difficult level for the poor readers, which may have resulted in floor effects. The performance of the reading-age controls in the present study is also pertinent to this point. Under conditions of high task difficulty, they also failed to show an effect of phonological similarity. Thus the abolition of the effect in poor readers does not indicate abnormal cognitive functioning. This conclusion is further supported by a recent study by Salamé and Baddeley (1986), which shows that adults too fail to exhibit a phonological similarity effect under conditions of high task difficulty. It seems likely that both of the groups in the present study responded to the difficult task demands by either reducing the amount of rehearsal or failing to rehearse altogether. Under conditions of high task difficulty, these subjects may have switched to a visual rather than a phonological code. Thus they may have become rather like normal younger children, who do not show phonological similarity effects until the age of 5 (Conrad, 1971), probably because they do not adopt a verbal rehearsal strategy until this age.

There is some evidence, however, that the poor readers used phonological processes less efficiently in immediate memory than did their reading-age controls, which is shown by the fact that their memory spans were significantly poorer than those of their controls. Impaired memory spans have consistently been observed in poor

Table 7
Experiment 4: Mean Percent Correct on Nonword Pronunciation

	Pseudohomophones		Nonwords		Easy Nonwords	
	M	*SD*	*M*	*SD*	*M*	*SD*
Poor readers	69.0	18.6	50.95	2.9	81.75	21.9
Reading-age controls	82.0	8.3	60.6	13.5	87.00	9.9

readers (Rugel, 1974), and it is important to determine the source of this difficulty if it is not directly related to whether poor readers use phonological coding in immediate memory. This impairment may well be due to the slowness to name objects, pictures, and colors that has often been observed in poor readers (e.g., Denckla & Rudel, 1976; Spring, 1976; Spring & Capps, 1974). Since several studies have shown that speech rate and naming speeds are directly related to memory span (Case, Kurland, & Goldberg, 1982; Hulme, Thomson, Muir, & Lawrence, 1984), it is probable that poor readers have impaired memory spans because they are slower to encode and rehearse incoming stimuli. Even adults seem to abandon verbal rehearsal when they are asked to remember very long lists of items, so it should not be surprising that poor readers do this too, nor that this happens in tasks where poor readers' chronological-age controls (who have superior memory spans) are still able to maintain rehearsal and thus exhibit phonological similarity effects.

In the rhyme judgment task in Experiment 2, there was evidence of deficient phonological processing in the poor readers in a task involving segmentation skills; these children were found to be less accurate at rhyme judgment than their reading-age controls (see also Bradley & Bryant, 1978). However, this was an overall accuracy difference, for both groups performed poorly when there was a mismatch between rhyme and orthography. All of the children were biased towards making "yes" responses to pairs of orthographically similar words, and "no" responses to orthographically dissimilar ones, which led to increased errors on both orthographically similar nonrhyming pairs (such as *lost-post*), and orthographically different rhyming pairs (such as *rude-food*). Skilled adult readers also show this pattern of performance (Johnston & McDermott, 1986), so it is not a feature of immature reading skill.

In the recognition memory task (Experiment 2), there were indications that the poor readers were using a qualitatively different form of memory coding from their reading-age controls. The poor readers were much better at remembering an item matched to an orthographically similar nonrhyming word (e.g., *post-lost*) than to an item matched to an orthographically dissimilar rhyming word, (e.g., *food-rude*). Exactly the opposite pattern was found with reading-age controls. The foil choices complemented this picture: the poor readers chose significantly more orthographically similar foils (e.g., *tone-done*) than phonologically similar ones (*come-plum*), whereas the reverse was the case for the reading-age controls. However, it could be argued that these patterns of performance reflect response biases in operation when the choices were made, rather than memory coding differences. According to this argument, one would say that the children failed to remember the word pairs and guessed from the items presented; because the poor readers were impaired at judging rhyme, they were less prone to making guesses based on phonological similarity. However, it is difficult to account for the poor readers' tendency to choose orthograhically similar items in the recognition memory task on these grounds, for they were no more sensitive to orthographic similarity than were their controls in the rhyme judgment task. Rack (1985) also found that poor readers showed recall based on orthographic rather than phonological similarity, but this was in a cued recall task, a type of task in which response biases are less likely to operate. Furthermore, his subjects were not, as they were in the present study, inferior to reading-age controls in rhyme judgment ability. Therefore, it seems unlikely, although not impossible, that the present results are due to response biases operating during the recognition memory task.

Since the poor readers did exhibit a number of phonological impairments in Experiments 1 and 2, it might be supposed that there are direct implications for their reading difficulties. It is often assumed that there is a direct relationship between reading skill and the ability to use phonological information in a variety of tasks. According to this view, it might be predicted that because of their impaired memory spans, difficulties in making rhyme judgments, and failure to use phonological information in recognition memory, the poor readers in the present study would fail to use a phonological approach to reading. However, as Wagner and Torgesen (1987) have recently pointed out, we still do not understand which aspects of phonological processing are causally related to the various component skills involved in learning to read. This is underlined by the fact that the poor readers in the present study, despite their impairment in a number of phonological processes, showed regularity and pseudohomophone effects of the same magnitude as that of their reading-age controls in Experiment 4, indicating a phonological reading strategy. These findings therefore replicate Waters et al.'s (1984) study, and they are consistent with the work of Backman, Bruck, Hebert, and Seidenberg (1984) and Treiman and Hirsh-Pasek (1985). The poor readers also had no difficulty in reading three-letter nonwords, although they were impaired in reading more complex nonwords. The successful pronunciation of simple nonwords by immature readers may be achieved by the use of low level grapheme-to-phoneme conversion rules, but more complex items may be decoded at the level of larger segments such as rhyme, (e.g., the *oast* in *poast*); these higher levels of segmentation have been found to be more susceptible to neurological degeneration (Shallice, Warrington, & McCarthy, 1983). Poor readers may have difficulty in recognizing these larger segments, and so show impaired nonword naming. Given that the poor readers also had difficulty in judging rhyme, these findings may suggest that the poor readers had impaired segmentation skills. Evidence to support this idea was shown in a further study of these same children (Holligan & Johnston, 1988), in which it was found that they performed more poorly than reading-age controls on a version of Bradley and Bryant's odd word out task.

Rack (1985) proposed that poor readers' utilization of orthographic rather than phonological information in cued recall or recognition memory tasks might be reflected in an orthographic approach to reading. However, this was not the case in the present study. What is evident is that although the poor readers named the words when making the rhyme judgments, they made little use of this phonological information in the recognition phase of the experiment. This is analogous in some ways to their problems in learning to read: they need much more exposure to the printed word than do their reading-age controls in order to achieve the same levels of word recognition ability. Thus the recognition memory findings may be more informative about why poor readers fail to progress at the normal rate in reading, rather than indicative of how they read.

A picture emerges here of a group of poor readers who, compared to reading-age controls, suffer from a phonological dysfunction that is limited to complex tasks requiring segmentation skills. Thus the poor readers had difficulty in judging rhyme and in pronouncing complex nonwords accurately. Tasks involving lexical decisions or the pronunciation of familiar items may utilize segmentation skills much less than tasks such as rhyme judgment, and this may explain why the poor readers performed similarly to their controls in these tasks. Thus the present group of poor readers exhibited phonological impairments in some tasks, but performed appropriately for their reading age in a number of others. This suggests that these poor readers did not suffer from a global phonological dysfunction. Future research should concentrate on delineating those components of phonological functioning in which poor readers are impaired, and it should examine what implications these deficiencies have for word recognition difficulties.

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APPENDIX A

Experiment 2: Stimuli Used in Rhyme Judgment Task

Type 1 Rhyming and Orthographically Different pairs		Type 2 Rhyming and Orthographically Similar pairs		Type 3 Nonrhyming and Orthographically Different pairs		Type 4 Nonrhyming and Orthographically Similar pairs	
coal	pole	need	weed	best	card	wash	cash
pond	wand	join	coin	soon	stay	both	moth
hawk	walk	fish	wish	rich	book	bowl	howl
rude	food	bang	hang	boil	safe	lost	post
peer	near	back	sack	king	nice	work	pork
come	plum	pink	sink	hard	wish	done	cone
rose	goes	fall	ball	feel	been	bead	dead
bull	wool	heat	beat	fill	care	harm	warm
farm	calm	snow	blow	play	shot	dull	pull
head	shed	miss	kiss	club	pile	hoot	foot
moan	bone	hide	wide	glad	limp	nose	lose
talk	fork	bite	kite	must	hard	fear	wear
been	clean	town	down	rang	milk	mood	good
fuse	news	gate	late	ripe	trip	tone	gone
soap	hope	take	bake	shut	send	love	move
dare	air	drip	grip	four	sick	wood	blood

APPENDIX B

Experiments 2 and 3: Stimuli Used in Recognition Memory Task

Cue	Target	Phonologically Similar Foil	Orthographically Similar Foil	Irrelevant Foils	
		Condition A			
cone	done	own		gaze	blur
tone	gone	sown		half	grey
foot	hoot	put		left	moon
wear	fear	hair		lace	itch
pork	work	chalk		horn	pike
warm	harm	form		mask	lump
bead	dead	heed		loop	halt
post	lost	toast		fail	each
bowl	howl	mole		free	bolt
both	moth	oath		pest	lend
wash	cash	posh		yarn	cage
lose	nose	dues		jerk	camp
		Condition B			
dare	air		are	what	tape
bone	moan		one	slab	hush
wool	bull		fool	sort	they
come	plum		dome	real	stab
near	peer		pear	time	rock
food	rude		hood	puff	torn
goes	rose		does	pipe	kept

APPENDIX C

Experiment 4: Regularity Task

Irregular Words		Regular Words	
High Frequency	Low Frequency	High Frequency	Low Frequency
both	touch	best	stuck
great	deaf	green	gate
heard	pint	bring	pest
shall	wool	still	dust
knew	lose	strong	luck
break	aunt	stick	wake
does	bury	door	gang
come	laugh	take	treat
build	doll	dance	base
gone	sew	kept	rub
bowl	soul	turn	mile
love	sword	fine	spade
foot	prove	tune	spear
blood	glove	along	slate
bread	broad	able	dive

APPENDIX D

Experiment 4: Pseudohomophone Task, Pronunciation of Pseudohomophones and Nonwords

Pseudohomophones		Nonwords	
loe	wotch	coe	cotch
hoase	teech	loase	spreed
bair	gole	nair	brise
moove	bloan	doove	doan
layd	blud	sayd	blum
gon	wosh	bon	mosh
luv	saive	druv	haive
poast	oan	loast	goan
woz	wurd	hoz	lurd
hoam	groe	soam	proe
flud	boath	brud	moath
wosp	bild	gosp	brode

APPENDIX E

Experiment 4: Pronunciation of Easy Nonwords

rop	lom	poy	nem	kun
wut	mun	yab	lub	dup
teg	keb	lat	ged	lig
fot	vin	nog	tut	sif

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