AN INVESTIGATION OF SPEECH PERCEPTION ABILITIES IN CHILDREN WHO DIFFER IN READING SKILL

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Abstract. Considerable evidence indicates that children who are poor readers have a phonetic coding deficit on linguistic short-term memory tasks. A previous study (Brady, Shankweiler, & Mann, 1983) had explored whether the initial perception of items might be the locus of the memory problem, and had demonstrated inferior speech perception abilities for poor readers with degraded stimuli. In the present study, the goal was to look more closely at perception under clear listening conditions. Third-grade good and poor readers were tested on a word repetition task with monosyllabic, multisyllabic, and pseudoword stimuli. Poor readers were significantly less accurate on the more demanding multisyllabic and pseudoword stimuli, though no group differences were obtained on speed of responding. The lack of reaction time differences between good and poor readers was corroborated on a control task in which verbal response time to nonspeech stimuli was measured. The reduced accuracy with clearly presented stimuli confirms the presence of subtle deficiencies in speech perception for children with reading difficulty and strengthens the hypothesis that poor readers' memory deficits may stem from less efficient encoding processes.

Evidence has been steadily mounting that the associates of early reading difficulty lie in the phonological domain. One of the central areas of research contributing to this evidence has involved studies of short-term memory (STM). Children with reading problems have repeatedly been observed to have deficient recall on STM tasks when compared with better reading peers. The role of phonological processes in this deficit has been implicated by several findings: First, the memory deficit for poor readers is observed only for stimuli that can be phonetically recoded such as letters, words, and pictures of nameable objects. When stimuli are presented for recall that are not easily given a phonetic code, good and poor readers perform comparably.

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This contrasting result has been obtained with tasks employing photographs of strangers, nonsense doodle drawings, symbols from an unfamiliar writing system, and with auditorily presented tones (Holmes & McKeever, 1979; Katz, Shankweiler, & Liberman, 1981; Liberman, Mann, Shankweiler, & Werfelman, 1982; Vellutino, Pruzek, Steger, & Meshoulam, 1973). Thus the limits in STM for children with reading difficulty are specific to tasks requiring phonetic coding.

Second, when the STM tasks consist of linguistic material, manipulations of phonetic dimensions of the stimuli generally affect the performance of young good readers more than that of young poor readers (Liberman & Shankweiler, 1979; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979). With strings of phonetically distinct (nonrhyming) stimuli, good readers show the usual superior recall for verbal material. When the phonetic confusability is increased by presenting rhyming items, the performance of good readers is impaired much more than the recall of poor readers. It has been reasoned that this pattern, also observed in adults, stems from the skilled readers being better able to form a sufficient phonetic code for temporary storage of information. Stimuli that minimize the phonetic contrasts between items in STM, such as lists of rhyming words, thus tend to have a greater effect on the recall of the good readers. Therefore, differential sensitivity to phonetic similarity by reading groups has been seen as a consequence of differing levels of skill in the use of a phonetic code.

Subsequent studies have indicated that poor readers employ a phonetic code, but do so less accurately than good readers. Examining the nature of errors on verbal STM tasks, both reading groups produce phonetically-based mistakes such as transpositions of phonetic elements. However, the incidence of these errors is more frequent for the children with reading difficulty (Brady, Mann, & Schmidt, 1985; Brady, Shankweiler, & Mann, 1983). Additional research indicates that poor readers are not worse on all components of language processing:[1] when other linguistic variables in STM tasks are experimentally varied, such as syntactic and semantic parameters, reading groups are equally affected (Mann, Liberman, & Shankweiler, 1980). Thus the memory deficits of poor readers are uniquely associated with phonetic requirements in STM, not with other aspects of language processing.

An important insight about the extent of the phonetic coding problem arises from the observation that reading groups differ in STM recall whether the lists are presented visually or auditorily (Brady et al., 1983; Brady et al., 1985; Mann et al., 1980; Shankweiler et al., 1979). This finding suggests that poor readers experience a general difficulty in the use of a phonetic code, rather than an impairment specific to the encoding of visual information.

To summarize, poor readers demonstrate short-term memory deficits only for stimuli that are phonetically recodable. These children show reduced sensitivity to rhyme and greater frequency of phonetic errors of transposition, providing further support that the deficit is related to phonetic skills. Lastly, these results are independent of the modality of presentation, pointing to a general phonetic processing deficit in STM.

The current evidence is consistent with the view that the short-term memory deficit of poor readers stems from deficiencies in the use of a phonetic code. In exploring the phonetic basis of the memory problem, we have been conducting experiments to determine whether the problem arises in perception with the encoding of stimuli. If so, poor readers can be expected to do less well on perception as well as on recall tasks than good readers. This finding was obtained in a previous study (Brady et al., 1983) in which third-grade poor readers performed less accurately than good readers on a speech perception task requiring identification of words presented in noise. In contrast, the reading groups did not differ in performance on a nonspeech control task with environmental sounds.

At the present we are working with the hypothesis that the difficulties of poor readers in speech perception and verbal STM tasks arise from a common source: the creation and maintenance of phonetic representations. From this approach, the efficiency with which the input is encoded will have consequences both in perception and in memory. Rabbitt (1968) carried out experiments with adults that supported this hypothesis. When digits were degraded slightly by the addition of noise, memory was observed to suffer, even though identification of the digits in isolation was still accurate. Rabbitt proposed that limited processing capacity was the basis for the reduction in memory span. That is, as increased resources were required for identification of the digits in noise, relatively less processing capacity was available for retaining the items in memory.

Similar explanations have been offered for the commonly observed developmental increases in STM (Chi, 1976; Dempster, 1981), and the individual differences in memory span for adults (Baddeley, Thompson, & Buchanan, 1975; Hoosian, 1982). Hulme, Thomson, Muir, and Lawrence (1984) report that although younger children recall less, the same linear function relates speaking rate to short-term memory for subjects ranging in age from four years old to adulthood. They suggest that speech rate can be seen as a measure of rehearsal speed, so that increases in speech rate, rather than in memory span per se, account for the observed gains in STM during development. Case, Kurland, and Goldberg (1982) likewise found that speed of word repetition correlated with memory span scores for children three to six years of age. These authors propose the slightly different explanation that basic operations in perception and memory become more efficient with experience, requiring less processing space, and that as a consequence more functional space exists for storage. In an interesting test of this, Case et al. equated six year olds and adults on speed of word repetition by manipulating word familiarity, and correspondingly found that the word spans for these two age groups were no longer different.

Given that the efficiency of phonetic processes appears to be related to normal developmental increases in memory span, it is of added importance to evaluate whether the STM differences associated with reading ability might arise from the efficiency of phonetic encoding. Since poor readers in the Brady et al. (1983) study made more errors repeating the speech-in-noise, it appears their perceptual skills are less well developed than those of children who are good readers. Therefore, it might also be the case that under clear listening circumstances the poor reader's encoding, though adequate, is less efficient (i.e., may require more processing resources) and may limit performance on recall tasks.

To test this line of reasoning, we wanted to investigate whether differences in efficiency in perception are present under clear listening conditions, since this is the way stimuli are presented for most STM experiments. In the Brady et al. (1983) study, no perceptual differences between reading groups had been observed on accuracy scores for a noise-free task with monosyllabic words. However, since both good and poor readers had been at ceiling performance levels, it may not have been a sufficiently sensitive procedure to assess group differences in perceiving clear stimuli.

If reading group differences in perceptual processing efficiency are present for clear listening, we speculated that this might take one or two forms: 1) poor readers might be slower at identifying or producing a phonetic utterance; 2) the quality of the phonetic representation might be less fully accurate for the poor readers. Under clear listening conditions with no time constraints and with relatively easy phonetic stimuli, poor readers could conceivably perform well with either or both of these processing limitations.

With these questions in mind we examined third-grade good and poor readers on a speech repetition task. Our aim was to look more closely at whether reading group differences in perception are evident when stimuli are presented clearly. The responses were scored for accuracy, and reaction time (RT) measures were collected to assess processing speed. Three kinds of stimuli were presented: monosyllabic words, multisyllabic words, and pseudowords. In this way the phonological demands of the task were varied in case monosyllabic words (previously tested) were not sufficiently difficult to process to reveal potential group differences. Therefore the length of the stimuli was increased in the multisyllabic condition and the familiarity was decreased in the pseudoword condition. Both of these are known to increase processing demands in adults and we expected this also to be true for children. We hypothesized that the reduced accuracy of poor readers on speech-in-noise (Brady et al., 1983) had reflected on-going differences in perceptual skills that are only apparent on somewhat demanding tasks. Consequently we predicted that poor readers would be less accurate than good readers on the more difficult multisyllabic and pseudoword stimuli, but that both groups would do well on the monosyllabic items.

The reaction time measure allows us to address the speed of processing issue raised in the developmental literature (e.g., Hulme et al., 1984). If group differences in RT were evident, we predicted that the good readers would be faster, indicating more rapid phonetic processing capabilities and possibly reflecting a developmental advantage.

Anticipating that differences in reaction time might be present for good and poor readers, a control task was included so it would be possible to focus on what aspect of the repetition task was implicated. In this task, subjects were presented with nonspeech tones to which they were to respond rapidly with a specified word. If potential group RT differences in the word repetition task were related to articulation speed, reading group differences should be maintained on the control task. If instead they stemmed from identification processes for a phonetic input, the tone stimuli should not generate group RT differences.

Methods

Subjects. The subjects were third-grade children from a suburban school district in southern Rhode Island. The school reading coordinator targeted the children she thought would qualify as good or poor readers. These children were then administered 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). In addition, the children were screened for hearing loss. Using a standard audiometer, each child's right and left ears were tested with tones at 500 Hz (25dB), 1000 Hz (20dB), 2000 Hz (20 dB), 4000 Hz (20 dB) and 8000 Hz (20 dB).

Children were selected as subjects if they met the following criteria: (1) To ensure appropriate classification as a good or poor reader, an individual was included only if the two scores on the Woodcock subtests were consistent (i.e., if both scores indicated a comparable level of reading ability.) (2) In order to limit the range of vocabulary skills, participation was restricted to those with PPVT-R IQ scores between 90 and 125. (3) Because of the auditory requirements of the experimental tasks, only children who passed the hearing screening were eligible. In accord with routine procedures, an individual passed the screening if no more than a single frequency on each ear was undetected. (4) Given the evidence that the speech perception skills of children continue to progress during elementary school years (Finkenbinder, 1973; Goldman, Fristoe, & Woodcock, 1970; Schwartz & Goldman, 1974; Thompson, 1963), selection of subjects was limited to those whose ages fell within a one year span (101-113 mos.).

Thirty children (15 good readers and 15 poor readers) met the requirements for inclusion in the study. The characteristics of the two reading groups are summarized in Table 1. The Woodcock test scores were non-overlapping for the good and poor reading groups. The 15 children who were designated good readers were clearly beyond third grade reading mastery, with a mean reading grade level of 7.8. The 15 children who were labeled poor readers had an average lag of nine months below their expected level ($\bar{x}=3.1$). Neither the ages, $F(1,28)=.26$, $p = .61$, nor the PPVT-R IQ scores, $F(1,28) = 1.23$, $p = 2.8$, of the good and poor readers were significantly different.

Table 1

Means for Third Grade Children Grouped According to Reading Achievement

Group	N	Age	IQ[a]	Reading Grade[b]
Good	15	8 yr. 9 mo.	108.1	7.8
Poor	15	8 yr. 10 mo.	104.5	3.1

[a] Peabody Picture Vocabulary Test

[b] From the average of the reading grade scores obtained on the Word Attack and Word Recognition subtests of the Woodcock Reading Mastery Tests, Form A.

Stimuli. Three sets of stimuli were used: (1) a set of 48 monosyllabic words; (2) a set of 24 monosyllabic pseudowords, and (3) a set of 24 multisyllabic words. In addition, a 24 item control task was employed.

Monosyllabic words. The monosyllabic word list (MONO) was the same as that used in a previous study (Brady et al., 1983). The words were chosen to control for syllable pattern, phonetic composition, and word frequency. There were 12 words for each of four syllabic patterns: CVC (consonant-vowel-consonant), CCVC, CCVCC, and CVCC. In addition, the words were chosen to provide a systematic phonetic set. Twenty words began with stop consonants (/b/, /d/, /g/, /p/, /t/, /k/), twenty words began with fricatives, or affricates (/tʃ/, /s/, /f/, /ʃ/, /dz/, /v/), and four began with liquids (/r/, /l/). The same distribution of phonemes occurred in word final position.

For each syllable and phoneme pattern, half of the words included were reported to have a high frequency of occurrence in children's literature and half to have a low frequency (Carroll, Davies, & Richman, 1971). The words used are presented in Table 2.

Table 2

Monosyllabic Stimuli

Words		Pseudowords
High Frequency	Low Frequency	
door	bale	dar
team	din	tem
road	lobe	rud
knife	mash	nauf
chief	chef	chife
job	fig	jeeb
grain	tram	grun
breath	grouse	brath
crowd	crag	crad
sleep	slag	slape
scale	spire	skell
speech	skiff	spoach
front	flint	frant
plant	clamp	plint
friend	frond	freend
clouds	glades	cleeds
blocks	drapes	blakes
planes	prunes	pleens
bank	kink	bink
chance	finch	chounce
list	rasp	liced
month	nymph	manth
child	vault	chauld
ships	shacks	shaps

Monosyllabic pseudowords. A set of 24 monosyllabic pseudowords (PSEUDO) was created by scrambling the medial vowels in the high frequency word set. In this way syllabic and phonetic patterns permissible in English phonology were maintained. The frequency of occurrence for these patterns was held constant for the word and pseudoword stimuli. Four adult speakers of English listened to the pseudoword items and judged whether each stimulus could be an acceptable word in English. Two vowel reassignments were made in accord with this feedback, resulting in the pseudoword stimuli listed in Table 2.

Multisyllabic words. The multisyllabic stimuli (MULTI) were three- and four-syllable nouns, all pronounced with stress on the first syllable. Since it is more difficult to control strictly for phonetic parameters in multisyllabic words, the items were selected to represent an array of syllabic and phonetic constructions. For each syllable length an equal number of high frequency and low frequency words was included, again based on word counts from Carroll et al. (1971). The multisyllabic stimuli are listed in Table 3.

Table 3

Multisyllabic Stimuli

High frequency	Low frequency
basketball	badminton
medicine	marmalade
furniture	refugees
neighborhood	saddlebag
vitamins	vinegar
satellite	silicone
television	dormitory
agriculture	anesthetic
helicopter	honeysuckle
supermarket	salamander
military	malnutrition
kindergarten	gladiators

Stimulus preparation. The stimuli were recorded by a phonetically trained male speaker, with each produced as the final word of a meaningful sentence. The sentences were later digitized at 20,000 samples/sec and each stimulus was excised from the sentence, using the Haskins WENDY waveform editing system. The items were arranged into a fixed random sequence for each set of stimuli and were then recorded onto one channel of a magnetic tape with an inter-stimulus-interval (ISI) of 4 secs. At the same time, a series of pulses to be used for timing purposes was recorded on the second channel of the magnetic tape. A pulse was aligned temporally with the onset of each stimulus item.

Control task. A brief 2000 Hz (100 ms) tone was recorded 24 times in two blocks of 12 trials on one channel of an audiotape. The ISI randomly varied with intervals ranging from 2.5 sec to 5 sec. To enable reaction time measures, a pulse was recorded on the second channel to co-occur with each tone.

Apparatus. The stimuli were replayed on a reel-to-reel tape recorder. One channel, containing the stimuli, was output to the subject and to the experimenter via open-air soft-cushion headphones. The other channel, with the pulses, was connected to the onset trigger of a timer. As each word or pseudoword was produced on the tape recorder, the pulse triggered the counter on the timer. The subject would repeat the stimulus, as rapidly as possible, speaking into a pair of microphones centered in front of the subject. One of the microphones contained a voice key, which would terminate the counter. The resulting reaction time, displayed digitally, was written by the experimenter and was output from a printer. Via the second microphone, the subjects' responses were recorded on audiotape. Transcriptions of the responses were also made during the testing session. The response tapes were listened to later in the day in order to corroborate the transcription and to allow any necessary corrections. The same apparatus was used for the control task.

Procedure. Each child was tested individually in a quiet room for three sessions. The first session included the Woodcock reading tasks and the Peabody Picture Vocabulary test. In the second session, occurring at least a week later, the children were given the hearing screening and the monosyllabic word reaction-time task. The third session, occurring approximately another week after the second, included the multisyllabic word RT task, the monosyllabic pseudoword RT task, and the control task. We elected to present the conditions in a single order that we felt would be easy for third graders to follow.

For the speech stimuli tasks, the subjects were asked to say what they heard as quickly as possible. While speed was encouraged, the children were also instructed to say the words distinctly. Prior to the RT tasks, the subjects practiced repeating words said by the experimenter and then practiced repeating preliminary items on the tape.

For the control task, subjects were instructed for the first twelve trials to say the word /cat/, as rapidly as possible, when a tone was heard. For the second block of twelve trials subjects were told to say /banana/ upon hearing a tone.

Results and Discussion

The responses were analyzed in terms of accuracy (number correct) and speed (reaction time).

Accuracy scores. The responses were scored for phonetic accuracy. Each item was scored as correct or incorrect. If a subject stuttered or stammered during a response, this was not counted as an error. Any other misproduction, changing the phonetic description of the item, was noted as an incorrect response. The results are presented in Figure 1. Since the order of presentation of conditions was not counterbalanced, comparisons between performance of reading groups will be made within each set.

On the *monosyllabic* words, which we had characterized as the least difficult set, the reading groups performed comparably, $F(1,28)=.79$, $p=.38$. More errors occurred on the low frequency words, $F(1,28)=39.79$, $p<.0001$, but this was true for both reading groups, as can be seen in the lack of a frequency x group interaction, $F(1,28)=.61$, $p=.44$. However, with the more demanding conditions, the poor readers produced significantly more errors. On

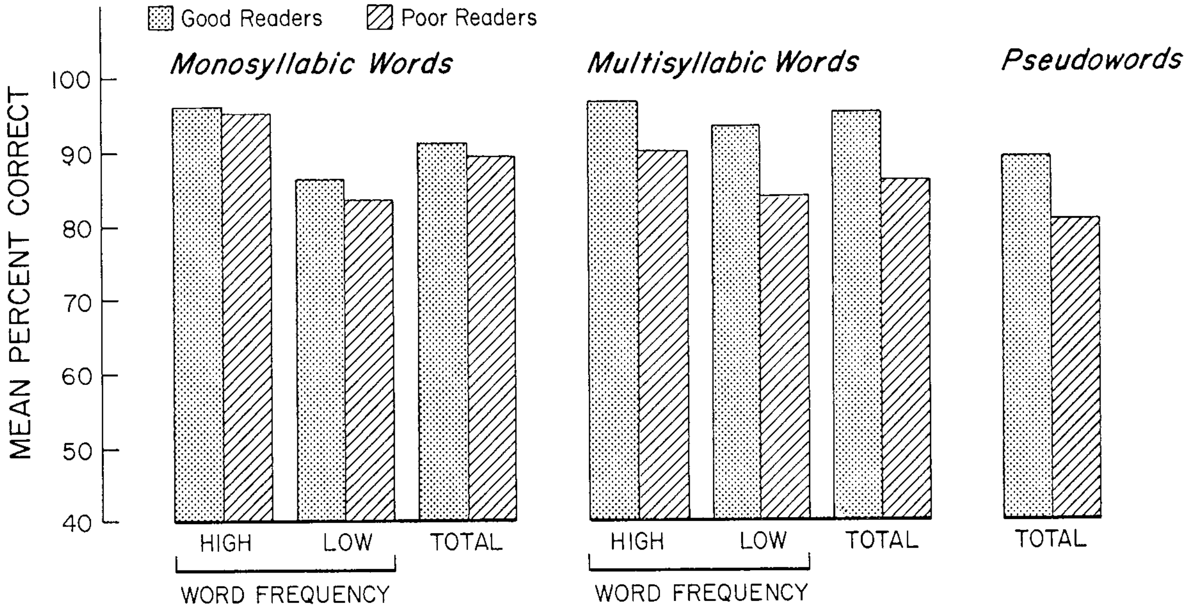

Figure 1. Accuracy performance of good and poor readers, plotted in mean percent correct.

the multisyllabic stimuli, group differences were obtained on the entire set, F(1,28)=8, p=.009, and on both the high frequency, F(1,28)=5.49, p=.03, and low frequency, F(1,28)=6.45, p=.02, stimuli. Once again there was an overall effect of word frequency, F(1,28)=7.78, p=.01, but this did not differ for good and poor readers, F(1,28)=.66, p=.42. An additional analysis was performed on the MULTI data, examining the effect of the length of the stimuli on the error rate. Both good and poor readers tended to produce more errors on the longer, four-syllable items, though this pattern was not significant, F(1,28)=3.43, p=.08. While longer utterances may be more difficult to process, the particular phonetic sequence required appears to be a more salient factor. For example, in the four syllable stimuli no errors were obtained on the item /salamander/ while many children mispronounced the cluster in /agriculture/.

Since word frequency effects were obtained on both the MONO and MULTI conditions, one might predict an even higher error rate on the pseudowords, given that subjects obviously have no prior familiarity with these utterances. For poor readers this looks to be the case: they produced the most errors on the pseudoword stimuli. Good readers, on the other hand, had fewer errors on average on the pseudoword stimuli than on the low frequency monosyllabic real words. The good readers appear to have benefited from the previous trials, getting more experienced with the task and perhaps getting more finely tuned to the phonetic requirements of the task (e.g., adjusting to the particular dialect of the speaker).[2] Thus the difference in performance between reading groups widened in the PSEUDO condition, again yielding significant results, F(1,28)=9.98, p=.004.

In sum, for accuracy measurements a noteworthy difference in performance was observed for the two reading groups. As we had predicted, the poor readers made significantly more errors on the multisyllabic and pseudoword conditions. The comparable effects of word frequency for both reading groups suggests that the perceptual problems of poor readers do not stem from possible differences in word knowledge. Our next step was to check whether IQ level might have been the underlying basis for these reading group results. Although the groups did not significantly differ on PPVT-R IQ scores, Crowder (1984) has pointed out that this may not adequately control for IQ factors. He argues that the size of the obtained group difference in IQ is not relevant in light of regression artifacts that may exist. To address this concern, one can test whether reading group differences in IQ might be responsible for the obtained results by recombining the subjects into high and low IQ groups. When this was done (high IQ: $\bar{x}=113.9$; low IQ: $\bar{x}= 98.5$), the conditions that had revealed significant reading group effects were reanalyzed and no significant IQ group differences were evident (MULTI: $F(1,28)=.91$, $p=.35$; PSEUDO: $F(1,28)=.21$, $p=.65$). These results support the conclusion that the findings of speech perception differences for the good and poor readers arise from factors related to reading ability per se.

Analysis of reaction time data. The mean reaction times of correct responses for the three stimuli sets are shown in Table 4. Reaction times are excluded from trials in which the response was incorrect and/or the subject's reaction time was not within the limits of 200-2000 ms.

Table 4

Mean Reaction Time (ms) for Correct Trials

	Monosyllabic Words			Multisyllabic Words			Pseudowords
	High Frequency	Low Frequency	Total	High Frequency	Low Frequency	Total	
Good	847.6	876.7	861.2	824.8	875.7	852.4	732.6
Poor	818.3	857.4	838.8	760.7	788.5	772.1	686.7

As described earlier, the conditions were presented in a single order (1. MONO; 2. MULTI; 3. PSEUDO), which we thought would be easy for third graders to perform. A general observation can be made that RT values get faster for successive blocks of trials (as is typical for adults), overcoming the processing requirements imposed by greater length or reduced word familiarity. However, these effects can be noted within conditions, as will be described below.

The major finding for this scoring procedure is that there are no significant differences in RT between reading groups for any condition: MONO, $F(1,28)=.21$, $p=.65$; MULTI, $F(1,28)=2.80$, $p=.12$; PSEUDO, $F(1,28)=.82$, $p=.37$. Further, although no group differences were significant, we were surprised that the poor readers, rather than being slower than good readers, were on average somewhat faster. This finding will be discussed below in relation to the error data.

With children as subjects, concerns might be raised about the reliability of reaction time data. However, the RT values suggest the subjects were seriously engaged in the task, and the results indicate systematic effects of linguistic parameters. For example, expected word frequency effects (less frequent items taking longer to initiate) were observed on both the monosyllabic lists, $\underline{F}(1,28)=27.63$, $\underline{p}<.0001$, and on the multisyllabic condition, $\underline{F}(1,28)=18.54$, $\underline{p}=.0002$, with no interaction of word frequency with reading groups (MONO: $\underline{F}(1,28)=.59$, $\underline{p}=.45$; MULTI: $\underline{F}(1,28)= 1.59$, $\underline{p}=.22$)

Had RT differences for good and poor readers been evident, we wanted to be able to focus on which aspect of the repetition task might have been responsible: identification of the input or articulation of the response. To do this, we administered the control task in which the speech identification process had been eliminated. Obviously, given the lack of reading group RT differences, the control results did not serve the original purpose. Nonetheless, the results do corroborate the lack of reading group RT differences in the word repetition tasks (monosyllabic control (/cat/): $\underline{F}(1,28)=1.0$, $\underline{p}=.33$; multisyllabic control (/banana/): $\underline{F}(1,28)=2.31$, $\underline{p}=.14$).

In sum, there is no indication that the efficiency of phonetic processing that is represented in reaction time data differs for good and poor readers. We must consider, then, why the reading groups did not differ in reaction time performance, but did contrast on accuracy scores. Traditionally, these two dependent measures of performance have been viewed as alternative ways of studying the same underlying processes (e.g., Eriksen & Eriksen, 1979; Lappin, 1978; Smith & Spoehr, 1974). However, evidence has been reported recently suggesting that speed and accuracy measures do not always reflect the same aspects of information processing (Santee & Egeth, 1982).

In the present study, speed/accuracy tradeoffs appear to be present for both good and poor readers. In Table 5, it can be seen that in some of the conditions significant negative correlations were obtained between RT and the incidence of errors. Our question is whether poor readers' tendency to have faster RTs might be contributing to the observed reading group error differences. For the monosyllabic condition this issue doesn't arise since the good and poor readers were not distinguished by error rate. In the multisyllabic task, the nonsignificant correlations between RT and errors indicate that other factors are the basis of the error performance. In the pseudoword condition, the two dependent measures were correlated, so an analysis of covariance was conducted on the error data using RT as the

Table 5

Correlations for Measures of Reaction Time and Error Rate

	Monosyllabic Words	Multisyllabic Words	Pseudowords
Good Readers	-.20	+.20	-.55*
Poor Readers	-.65*	-.24	-.48*

*$\underline{p}$ < .01

covariate. Significant reading group differences were still evident, $F(1,27)=9.1$, $p=.006$, again suggesting that while error and accuracy scores in part arise from the same processes, other factors are uniquely contributing to the error scores.

To reiterate, the results indicate that poor readers are less accurate in phonetic processing, but are not slower. It appears that it is necessary to have a somewhat demanding task in order to discern reading group differences in phonetic ability. On the more difficult tasks, omega squared was calculated to determine the proportion of variance accounted for by the accuracy of phonetic processing. The results are as follows: MULTI = .14; PSEUDO = .21. These effect sizes indicate that a fair amount of the performance differences between reading groups can be attributed to phonetic processes in perception.

Conclusion

In this study we looked more closely at good and poor readers' performance in speech perception with nondegraded stimuli in an attempt to explore the basis of poor readers' short-term memory deficits. On repetition tasks, RT and accuracy measures were taken for monosyllabic, multisyllabic, and pseudoword stimuli for third-grade good and poor readers. Although there was no indication of reaction time differences for the reading groups, the good readers were significantly more accurate than the poor readers for the more demanding multisyllabic and pseudoword stimuli.

Our framework has been to consider whether differences in phonetic processing efficiency might be central to short-term memory function, which in turn plays a role in spoken and written language comprehension. Assumptions are being made in this approach that have been generally validated in research on cognitive processes. One is the assumption of a limited-capacity working memory system (Baddeley & Hitch, 1974). Second, within that system sub-processes are assumed to become more automatic with experience and to require less resource allocation (LaBerge & Samuels, 1974). Perfetti (1985) has formalized this approach in his "Verbal Efficiency Theory of Reading Ability" and provides a strong case for the role of the efficiency of lower level processes in language processing, and specifically in reading.

Here we are examining one such lower level process, phonetic skills, to attempt to explicate the nature of the linguistic deficits occurring for poor readers on memory tasks. Given the consistent evidence of a relationship between speed of processing and memory span for adults (Baddeley et al., 1975), as well as developmentally (Case et al., 1982; Hulme et al., 1984), it seemed plausible that the perception and memory deficits of poor readers might stem from reduced efficiency of perceptual processes and, consequently, from limited STM resources. Our results were mixed: the quality of responses was significantly less accurate for the more phonetically demanding stimuli, though somewhat surprisingly the poor readers were not found to be slower at initiating a phonetic response. In a subsequent study (Merlo & Brady, in preparation) this pattern has been replicated. Research by others generally conforms to this picture as well. For somewhat demanding speech tasks (speech-in-noise, Brady et al., 1983; multisyllabic words, Snowling, 1981; phonologically difficult phrases, Catts, 1984; tongue twisters, Merlo & Brady, in preparation), poor readers have repeatedly been observed to produce more errors. On the other hand, reaction time measures for tasks entailing creation of a phonetic representation (e.g., object naming, color naming, digit naming, word naming) have generally not revealed reading group differences in RT unless the stimulus involved orthographic information (Katz & Shankweiler, 1986; Perfetti, Finger, & Hogaboam, 1978; Stanovich, 1981). However, there are some indications that differences in naming speed may be present with younger children or more disabled readers (Blachman, 1981; Denckla & Rudel, 1976a, 1976b; Spring & Capps, 1974). In toto, these findings suggest that the important differences in perceptual operations between good and poor readers rest not with the rate of processing, but with the accuracy of formulating phonetic representations.

To summarize, in the present study we have extended previous observations of inferior perception by poor readers with speech-in-noise to perceptual deficits with clearly presented stimuli. These results strengthen the hypothesis that the memory deficits commonly observed in poor readers for linguistic material may derive from the perceptual requirements of the task, that is, from less efficient encoding of the phonetic items.

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Footnotes

[1] However, it may well be the case that low level difficulties creating a phonetic representation in STM may have consequences on higher processes such as comprehension (cf. Mann, 1984; Perfetti, 1985).

[2] This fits unreported observations in previous research we've conducted that both good and poor readers tend to produce errors at the beginning of a demanding speech task, but good readers show more rapid improvement. It would be interesting in future work to evaluate this aspect of phonological competence specifically for good and poor readers.