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SPEECH REPETITION ABILITIES IN CHILDREN WHO DIFFER IN READING SKILL*

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A previous study (Brady, Shankweiler, and Mann, 1983) demonstrated inferior speech repetition abilities for poor readers with degraded stimuli. The present study, in contrast, used clear listening conditions. Third-grade average and below-average readers were tested on a word repetition task with monosyllabic, multisyllabic, and pseudoword stimuli. No group differences were obtained on speed of responding, and the lack of reaction time differences between reading groups was corroborated on a control task which measured verbal response time to nonspeech stimuli. However, below average readers were significantly less accurate at repeating the multisyllabic and pseudoword stimuli. This evidence is compatible with the hypothesis that encoding difficulties contribute to the memory deficits characteristic of poor readers.

Key words: phonological encoding, repetition, reading difficulties

INTRODUCTION

Evidence has been steadily mounting that the origins of early reading difficulty lie in the phonological domain. In addition to various indications that metaphonological

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processes are critical to reading acquisition, a number of underlying phonological processes have been observed to be related to reading ability. Children having difficulty learning to read have demonstrated deficient performance in short-term memory, in speech perception, in speech production, and in lexical access, although the nature of these deficiencies is still poorly understood (for reviews, see Brady, 1986; Liberman and Shankweiler, 1985; Wagner and Torgesen, 1987). In the present research, performance on word-repetition tasks by third-grade children was examined as a step toward delineating the extent of phonological difficulties for less-skilled readers.

In a previous study, we found that poor readers performed less accurately than good readers on a repetition task requiring identification of words presented in noise (Brady *et al.*, 1983). However, the reading groups did not differ on a nonspeech control task with environmental sounds. Therefore, contrary to claims (Tallal and Stark, 1982) that general auditory processes are associated with reading skill, the results pointed to a specific difficulty at the phonological level (see also Palley, 1986).

Our hypothesis is that the difficulty observed in encoding phonological information is not restricted to perception tasks but occurs at a more abstract level, whenever it is necessary to create and maintain a phonological representation. From this approach, the difficulties of poor readers on verbal perception, production, and short-term memory tasks arise, at least in part, from a common source: the requirement to phonologically encode a linguistic signal.

A number of findings fit with the suggestion that a similar operating system serves the perception, storage, and production of phonological structures, and that efficiency of encoding may set limits on performance. First, research by Rabbitt (1968) supports a link between perception and memory. When digits were degraded slightly by the addition of noise, memory in adults 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. Second, an association between speech production and memory has been proposed as the basis of developmental increases in STM capacity and of individual differences in memory span in adults (Case, Kurland, and Goldberg, 1982; Baddeley, Thomson, and Buchanan, 1975; Hoosian, 1982). Hulme, Thomson, Muir, and Lawrence (1984) report that young children both recall less and articulate more slowly than older individuals, and that 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 *et al.* (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 hypothesis, 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. Further evidence for the interrelationship of underlying phonological processes in memory and production has emerged from the study of concordant error patterns by adults in STM tasks and in spontaneous speech production (see Ellis, 1979, for a review).

Against this backdrop of research on phonological processes in children and adults, the question emerges as to whether the phonological problems of poor readers on various language tasks have a common basis. In particular, do the fairly ubiquitous memory difficulties of poor readers stem from less efficient encoding abilities? Since poor readers in the Brady *et al.* (1983) study made more errors repeating speech in noise, it appears their perception and/or production skills are less well developed that those of good readers. If this is true, then poor readers' encoding, though usually adequate, may be less efficient even under good listening conditions and could limit performance on a variety of verbal tasks. In the Brady *et al.* (1983) study, no performance differences between reading groups were observed on accuracy scores for a noise-free task with monosyllabic words. However, since both good and poor readers were at ceiling performance levels, the procedure may not have been sufficiently sensitive to assess group differences in encoding clear stimuli. A limited amount of research using repetition tasks has reported poor readers to be inferior with clearly presented multisyllabic words (Snowling, 1981) and phonologically complex phrases (Catts, 1986: though for this task memory requirements may be a factor).

If reading group differences in phonological processing are present for clear listening, poor readers' deficit might take one of two forms: (1) Poor readers might be slower at identifying or producing a phonetic utterance. (2) The quality of the phonological representation might be less 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. An alternative proposal has been offered by Snowling, Goulandris, Bowlby, and Howell (1986). They report that the perceptual difficulties of poor readers are restricted to nonlexical items (i.e., nonsense words). Snowling *et al.* hypothesize that lexical and nonlexical verbal stimuli require different processing, and that poor readers are deficient only in nonlexical analysis procedures.

The present study investigated whether reading group differences in encoding are present under clear listening conditions and whether lexicality of items is a determining factor. Two groups of third-grade children (above- and below-average readers) were tested on speech repetition tasks with three kinds of stimuli: monosyllabic words, multisyllabic words, and pseudowords. The responses were scored for accuracy and for speed. The monosyllabic words replicated the stimuli in the previous study. The other two conditions were added to increase the phonological demands of the task and contrasted in terms of lexicality.

Anticipating that differences in reaction time (RT) might be present between good and poor readers, a control task was included to focus on the articulatory aspect of the repetition task. In this control 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 persist on the control task. If instead group differences stemmed from the perceptual requirements of the word repetition task, or from compiling the perceived information for output, the groups should not differ in performance on the tone stimuli.

METHOD

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 0.5 kHz (25 dB), 1.0 kHz (20 dB), 2.0 kHz (20 dB), 4.0 kHz (20 dB), and 8.0 kHz (20 dB).

Children were selected as subjects if they met the following criteria: (1) To ensure appropriate classification as an above- or below-average 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, and Woodcock, 1970; Schwartz and Goldman, 1974; Thompson, 1963), selection of subjects was limited to those whose ages fell within a one year span (101–113 months).

Thirty children (15 above-average and 15 below-average) 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 groups. The 15 children who were designated above-average readers were clearly beyond third-grade reading mastery. The children who were labeled below-average readers had an average lag of nine months below their expected level for the time of year when testing was conducted and had all been identified by the school reading coordinator as having reading problems. Many were receiving supplemental remedial reading instruction. The reading coordinator and the school psychologist offered the opinion that the Woodcock-Johnson reading-grade equivalents overestimate a child's reading level. Nonetheless, our goal of obtaining two groups of children clearly separated in reading ability was achieved. Neither the ages [$F(1, 28) = 0.26$, $p = 0.61$] nor the PPVT–R IQ scores [$F(1, 28) = 1.23$, $p = 0.28$] of the good and poor readers differed significantly.

TABLE 1

Means for third grade-children grouped according to reading achievement

Group	N	Age	IQ[a]	Reading Grade[b]
Above average	15	8 yr. 9 mo.	108.1	7.8
Below average	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 words were the same words used in the previous study (Brady *et al.*, 1983). The words were chosen to control for syllable pattern, phonetic composition, and word frequency. For each syllable and phoneme pattern, half the words included had a high frequency of occurrence in children's literature and half had a low frequency (Carroll, Davies, and Richman, 1971). The words are presented in Table 2.

Monosyllabic pseudowords. A set of 24 monosyllabic pseudowords 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 and the frequency of occurrence for these patterns was held constant for the word and pseudoword stimuli.[1] Four adult speakers of English listened to the pseudowords and judged whether each 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 were three- and four-syllable nouns. Since it is more difficult to control for phonetic characteristics in multisyllabic words, the items were selected to represent a variety of syllabic and phonetic constructions. For each syllable length an equal number of high frequency and low frequency words was included. The multisyllabic stimuli are listed in Table 3.

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[1] One of the reviewers made the important observation that the monosyllabic words and pseudowords may have differed, however, in terms of the frequency of the *groups* of phonemes contained. For example, the /ab/ of 'job' is a common -VC group. The /ib/ of 'jeeb' is less common. If encoding programs involve larger groupings of phonemes, the pseudowords are not necessarily matched to the words.

TABLE 2

Monosyllabic stimuli

Words: High frequency	Words: Low frequency	Pseudowords
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

Stimulus preparation. The stimuli were produced as the final word of a meaningful sentence by a phonetically trained male speaker. 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 in 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 sec. At the same time, a series of pulses to be used

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

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 200 Hz (100 msec) 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 of the timer. The subject repeated the stimulus as rapidly as possible, speaking into a pair of microphones. One of the microphones contained a voice key which terminated the counter. The resulting reaction time was written down by the experimenter. 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, 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 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

Accuracy scores

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 that changed the phonological description of the item was scored as incorrect. 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, the reading groups performed comparably [$F(1, 28) = 0.79$, $p = 0.38$]. More errors occurred on the low frequency words [$F(1, 28) = 30.39$, $p < 0.0001$], but this was true for both reading groups, as can be seen in the lack of a frequency X group interaction [$F(1, 28) = 0.61, p = 0.44$]. On the multisyllabic stimuli, group differences were obtained [$F(1, 28) = 8$, $p = 0.009$]. An overall effect of word frequency was obtained [$F(1, 28) = 7.78$, $p = 0.01$], but there was no interaction with reading group [$F(1, 28) = 0.66$, $p = 0.42$]. An additional analysis was performed on the multisyllabic word data, examining the effect of the length of the stimuli on the error rate. Both above- and below-average readers tended to produce more errors on the longer, four-syllable items, though this pattern was not significant [$F(1, 28) = 3.43$, $p = 0.08$]. 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 "salamander" while many children mispronounced the first cluster in "agriculture" (e.g., "ajiculture"). The group difference was also significant in the pseudoword condition, [$F(1, 28) = 9.98, p = 0.004$].

Although the groups did not significantly differ on PPVT–R IQ scores, Crowder (1984) has pointed out that IQ factors still may not be adequately controlled and may contribute to performance differences between the reading groups. He argued that the

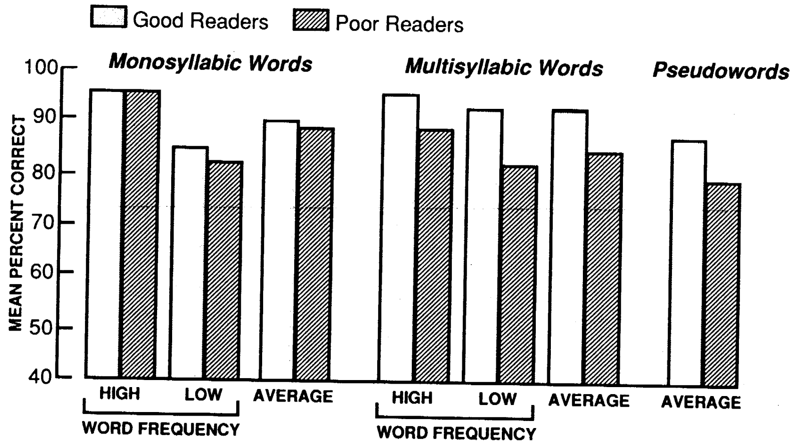

Fig. 1. Accuracy performance of good and poor readers, plotted in mean percent correct.

size of the obtained group differences 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 [multisyllabic: $F(1, 28) = 0.91, p = 0.35$; pseudoword: $F(1, 28) = 0.21, p = 0.65$]. These results support the conclusion that the findings of speech repetition differences for the good and poor readers arise from factors related to reading ability *per se*.

In sum, a noteworthy difference in performance was observed for the two reading groups on accuracy measurements. As we had predicted, the poor readers made significantly more errors in the multisyllabic and pseudoword condition. The comparable effects of word frequency for both reading groups suggest that the errors of poor readers do not stem from possible differences in word knowledge.

Reaction times

The mean reaction times for correct responses for the three stimulus sets are shown in Table 4. Reaction times were excluded from trials in which the response was incorrect and/or was not within the limits of 200-2000 msec.

As described earlier, the conditions were presented in a single order (1. monosyllabic; 2. multisyllabic; 3. pseudoword), which we thought would be easy for third graders to perform. Note that RTs get faster for successive blocks of trials. However, the effects of word length and word familiarity can be noted within conditions, as will be described below.

TABLE 4

Mean reaction time (msec) for correct trials

Reading group	Monosyllabic words Frequency High	Low	Avg.	Multisyllabic words Frequency High	Low	Avg.	Pseudowords
Above average	847.6	876.7	861.2	824.8	875.7	852.4	732.6
Below average	818.3	857.4	838.8	760.7	788.5	772.1	686.7

There were no significant differences in RT between reading groups for any condition: monosyllabic [$F(1, 28) = 0.21$, $p = 0.65$]; multisyllabic [$F(1, 28) = 2.80$, $p = 0.12$]; pseudoword [$F(1, 28) = 0.82$, $p = 0.37$]. Although no group differences were significant, the poor readers were on average somewhat faster than the good readers. This finding will be discussed further below.

The RT data suggest the subjects were seriously engaged in the task since there were systematic effects of linguistic parameters. For example, word frequency effects (less frequent items taking longer to initiate) were observed for both the monosyllabic [$F(1, 28) = 27.63$, $p < 0.0001$] and the multisyllabic conditions [$F(1, 28) = 18.54$, $p = 0.0002$], with no interaction of word frequency with reading groups (monosyllabic: [$F(1, 28) = 0.59$, $p = 0.45$]; multisyllabic: [$F(1, 28) = 1.59$, $p = 0.22$]).

Given the lack of reading group RT differences, the control task did not serve the original purpose. Nonetheless, the results do corroborate the lack of reading group RT differences in the word repetition tasks (monsyllabic control (cat): [$F(1, 28) = 1.0$, $p = 0.33$]; multisyllabic control (banana): [$F(1, 28) = 2.31$, $p = 0.14$]).

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 was whether below average readers' tendency to have faster RTs might be contributing to the observed reading group error differences. For the monosyllabic condition this issue does not 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 covariate. Significant reading group differences were still evident [$F(1, 27) = 9.1$, $p = 0.006$], again suggesting that while error and accuracy scores in part arise from the same processes, other factors are uniquely contributing to the error scores.

TABLE 5

Correlations for measures of reaction time and error rate

	Monosyllabic words	Multisyllabic words	Pseudowords
Above average readers	–0.20	+0.20	–0.55*
Below average readers	–0.65*	–0.24	–0.48*

* $p < 0.01$

To summarize, the results indicate that below average readers are less accurate in the repetition task, but are not slower. It appears that it is necessary to have a somewhat demanding task in order to discern reading group differences in phonological ability. On the more difficult tasks, the statistical power was calculated (omega squared) to determine the proportion of variance accounted for by the accuracy of phonological processing. The results are as follows: multisyllabic = 0.14; pseudoword = 0.21. These effect sizes indicate that a fair amount (Cohen, 1977) of the performance differences between reading groups can be attributed to phonological processes in perception.

CONCLUSIONS

In this study we investigated whether below average readers have less proficient phonological processes than do above average readers on speech repetition tasks with nondegraded stimuli. Reaction time and accuracy measures were taken for monosyllabic, multisyllabic, and pseudoword stimuli for third-grade readers above and below average. Although there was no indication of reaction time differences between the reading groups, the below average readers were significantly less accurate for the more demanding multisyllabic and pseudoword stimuli. Thus speech repetition difficulties are present for below average readers not only when stimuli are embedded in noise, as previously found, but also under clear listening conditions, and regardless of whether the stimulus is a real word. This outcome has several implications.

First, the hypothesis by Snowling *et al.* (1986) that poor readers encounter difficulty only with nonlexical items has not been confirmed. Here repetition difficulties by poor readers were evident not only for pseudoword stimuli but also for multisyllabic real words, even though the groups did not differ in lexical knowledge (vocabulary). Thus, we are inclined to conclude that poor readers' encoding processes are less efficient for all speech stimuli.

Second, the results in this study suggest that the important differences in encoding operations between good and poor readers rest not with rate of processing, but with accuracy of formulating phonological representations. Our findings have been replicated in a subsequent study (Rapala and Brady, in press), and research by others generally conforms to this picture as well. For somewhat demanding speech repetition tasks (speech-in-noise, Brady *et al.*, 1983; multisyllabic words, Snowling, 1981; phonologically difficult phrases, Catts, 1986; tongue twisters, Rapala and Brady, in press), poor readers have been observed to produce more errors. On the other hand, reaction time measures for tasks entailing creation of a phonological 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 and Shankweiler, 1986; Perfetti, Finger, and Hogaboam, 1978; Stanovich, 1981). However, differences in naming speed may be present with younger children or more disabled readers (Blachman, 1983; Denckla and Rudel, 1976a; 1976b; Spring and Capps, 1974), or it may be necessary to employ more sensitive measures of speed of processing in order to discern group differences.

Third, it remains to determine the basis of the accuracy difficulties for poor readers, and the correspondence among accuracy difficulties in perception, production, memory, and lexical access tasks. The inferior performance of poor readers on repetition tasks may stem from problems perceiving the stimuli, from problems producing them quickly and accurately, or from difficulties in encoding that may be common to all phonological tasks. One of our goals in undertaking the present study was to consider whether difficulties in encoding might contribute to the memory deficits noted for poor readers. Thus it was necessary to demonstrate encoding difficulties not only for speech in noise, as was done previously, but also for clearly presented speech, since auditory memory tasks for reading groups are presented in clear listening conditions.[2] The present findings, then, indicate that it would be worth pursuing whether individual and reading group differences in memory performance derive from the encoding requirements of the task. In a subsequent study (Rapala and Brady, in press) we investigated the relationship of phonological processing skills to short-term memory recall, and obtained significant correlations between the accuracy of phonological processes (multisyllabic word repetition and tongue-twister production) and verbal short-term memory span. This pattern was observed both in a developmental study with 4–8-year-olds and in an experiment with third-grade good readers and poor readers. In future work the basis of reduced accuracy by poor readers on phonological tasks needs to be explored, and it will be necessary to confirm the reported relationship between phonological processing and memory span. Further, it will be important to assess why speed of articulation correlates so highly with memory capacity in developmental studies, yet does not appear to be related to memory differences between good and poor readers.

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[2] As noted in the introduction, our hypothesis is that whenever a verbal stimulus is presented, whether visually or auditorily, it is necessary to phonologically encode the stimulus at an abstract level, independent of input modality. Accordingly, one could account for parallels found between performance on visual and auditory memory tasks by good and poor readers for stimuli requiring formation of a phonological code (e.g., Shankweiler, Liberman, Mark, Fowler, and Fischer, 1979; Katz, Shankweiler, and Liberman, 1981).

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