The word length effect in children with language impairment

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Abstract

Two types of serial word recall tasks (full verbal recall and probed recall) were administered to 11 children with language impairment and 22 language-normal children matched for productive language or chronological age. The methods were designed to take into account age-related differences in the use of subvocal rehearsal, as measured by the word length effect. The word length effect was significant for all three groups in full recall, but not in probed recall, supporting the hypothesis that children with language impairment demonstrate limited capacity for processing verbal output. Discussion focuses on the importance of considering developmental factors in measuring short-term memory effects in children with language impairment.

Learning outcomes: As a result of this activity, the participant will be able to describe the phonological loop hypothesis and discuss the interactions between working memory and language performance in children with language disorders.

Keywords: Working memory; Phonological loop; Serial word recall; Rehearsal; Language impairment; Language disorder; Children

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In the past decade, there has been an accumulation of evidence supporting a positive relationship between the development of language abilities and short-term memory functioning in normally developing children (Adams & Gathercole, 1995; Gathercole & Baddeley, 1989; Gathercole, Willis, Emslie, & Baddeley, 1992; Leather & Henry, 1994; Michas & Henry, 1994; Speidel, 1993). Such studies indicate that performance on a range of short-term memory tasks tends to be better in children who are good readers (Leather & Henry, 1994), have good oral language skills (Speidel, 1993), have faster rates of articulation (Baddeley, 1986; Cohen & Heath, 1990; Stigler, Lee, & Stevenson, 1986), and good vocabulary skills (Gathercole & Baddeley, 1989; Gathercole et al., 1992; Michas & Henry, 1994).

Conversely, children who have difficulty learning language, such as language-impaired children, tend to do poorly relative to normally developing children on measures of short-term memory (Ellis Weismer, Evans, & Hesketh, 1999; Gathercole & Baddeley, 1990; Gillam, Cowan, & Day, 1995; Kirchner & Klatzky, 1985; Shear, Tallal, & Delis, 1992; Sininger, Klatzky, & Kirchner, 1989). Such correlations have led to the assertion that short-term memory skills are directly involved in language learning (Gathercole & Baddeley, 1990; Gathercole et al., 1992), and that language impairment may result from poor short-term memory function (Gathercole & Baddeley, 1990). The hypotheses advanced to explain the nature and source of the difficulties are numerous (see Windsor, 2002 for a review). In general, children with language impairment tend to recall less information; however, findings are inconsistent with respect to the reasons for this diminished performance. One explanation is that poor performance on both language and short-term memory tasks can be explained by general cognitive processing deficits, such as diminished processing capacity (Ellis Weismer et al., 1999) or decreased processing rate (Lahey, Edwards, & Munson, 2001). Another proposal is that language impairment results from a breakdown specifically in the short-term memory system that deals with auditory–verbal information (Gathercole & Baddeley, 1990).

The latter account is based on the working memory model developed by Baddeley and coworkers (Baddeley, 1976; Baddeley & Hitch, 1974; Hitch & Halliday, 1983; Vallar & Baddeley, 1984). This model consists of a three-part system, containing a central executive, which controls attention and selects and operates other relevant processes, a visuo-spatial sketchpad, for temporary storage and manipulation of visual information, and a phonological loop, for the temporary storage and manipulation of speech-based information. It is the phonological loop portion of this model that has been most closely associated with language development.

The phonological loop is composed of a phonological store and a rehearsal process, both of which are limited in capacity, and both of which deal exclusively with speech and speech-like information. Together, the phonological store and the rehearsal process form an information “loop,” allowing auditory information to be recirculated until it can be more deeply processed. Rehearsal, the process of subvocal repetition, refreshes memory traces by recycling information back into the phonological store.
Of critical importance to the model is the claim that the rate of subvocal rehearsal is determined by the speaker’s rate of overt articulation, in that the faster the rate of articulation, the faster the rate of rehearsal, and consequently, the greater the amount of information that can be recalled (Baddeley, 1976, 1986, 1990; Baddeley, Lewis, & Vallar, 1984). This claim is based on the predictable, linear relationship between articulatory rate and short-term memory span that has been documented repeatedly in comparisons of adults with differing rates of speech (see Baddeley, 1986, 1990 for an overview). In addition, developmental increases in articulatory rate are linearly related to increases in short-term memory span (Hulme, Thomson, Muir, & Lawrence, 1984; Nicolson, 1981).

Another form of evidence offered to support the articulatory rate hypothesis is the word length effect. The word length effect refers to participants’ superior recall of lists of short versus long words. For example, the list “bat, key, cup, man, duck” is likely to be more completely recalled than the list “hamburger, alligator, Halloween, tuition, metaphor.” Fewer words can be recalled from lists containing longer words because more time is needed to subvocally repeat longer words. This slows the rate of rehearsal and allows more information to decay from the short-term store.

Investigators have interpreted the word length effect (the tendency to recall lists of short words better than long words) as evidence that articulatory rate is an important determiner of short-term memory span (see Baddeley, 1986, 1990). In individual subjects and in aggregate data, the word length effect is commonly used as evidence that rehearsal has taken place (e.g., Baddeley, 1990; Baddeley et al., 1984; Baddeley, Thomson, & Buchanan, 1975; Gathercole & Baddeley, 1990; Stigler et al., 1986; van der Lely & Howard, 1993).

Baddeley’s (1986) working memory model has provided a useful framework for examining specific patterns of performance with respect to adults with neurological impairments. As the model has been extended to explain children’s performance, however, it has received some criticism (Cohen & Heath, 1990; Cowan et al., 1994; Henry, 1991a, 1991b; Henry, Turner, Smith, & Leather, 2000). A fundamental question has been whether it can be assumed that adult models of short-term memory are applicable to children, whose cognitive systems have not matured (Henry 1991b). There are numerous sources of evidence that children are not born able to rehearse, rather that they develop rehearsal skills from the age of seven on. A variety of studies, indicate, for example, that children do not engage in spontaneous, overt rehearsal before the age of seven or eight (Cuvo, 1975; Kail, 1990; Ornstein, Naus, & Stone, 1977), that they become better able to rehearse deliberately with age (Hagen & Kail, 1973; Keeney, Cannizzo, & Flavell, 1967), and that the nature of their rehearsal changes over time (Bray, Justice, & Zahm, 1983; Cuvo, 1974; Kail, 1990; Moely, Olson, Halwes, & Flavell, 1969), perhaps developing gradually from a general naming strategy (see Henry et al., 2000 for a review). In addition, explicit rehearsal training does not improve young children’s performance as it does that of older children and adults (Henry, 1991a).

Although normally developing children as young as four years of age have demonstrated the word length effect (and, by extension, rehearsal) in some tasks,
(e.g., Hitch, Halliday, Dodd, & Littler, 1989; Hulme, 1987) these accounts rest on the assumption that rehearsal is the only underlying cause of the word length effect, an assumption that has been called into question (Cohen & Heath, 1990; Cowan et al., 1994; Henry, 1991b; Monsell, 1987). There is substantial evidence that, particularly when children are involved, the word length effect can be influenced by factors other than rehearsal, including rate of overt articulation during the recall phase (Henry, 1991b), word identification time (Dempster, 1981), cognitive and perceptual capacity (Cohen & Heath, 1990), speed of memory search (Cowan et al., 1994; Sininger et al., 1989), and response planning time (Sininger et al., 1989). Cowan et al. (1994) noted that while intersubject differences in some of these processes do not typically correlate with differences in span between adults, there is evidence for a correlation with span differences between children, for whom various aspects of cognitive processing may be less automatic and more effortful. Gathercole, Adams, and Hitch (1994) conducted a series of experiments that investigated the word length effect in verbal recall tasks by four-year-olds, and concluded that children at that age do not rehearse. They also suggested that some children might have enough capacity in the phonological store to maintain up to five list items without use of subvocal rehearsal, and that delays relating to output of list items could produce a word length effect.

This latter suggestion was also made by Henry (1991b), who noted that overt production of words during the recall phase (rather than during rehearsal) would differentially affect the number of short and long words that could be recalled. Since long words take longer to produce, more time elapses between presentation and completion of response, and memory traces in the phonological loop have more time to decay. Another possibility Henry (1991b) discussed was that there may be some sort of output buffer holding response plans which is itself limited in capacity, and from which traces might decay during the recall phase of a short-term task. If longer words took up more space in the output buffer, fewer long than short words could be recalled.

To test this hypothesis, Henry (1991b) employed a Probed Recall (PR) task to elicit the word length effect. The PR task required subjects to recall lists of words, but rather than repeating the full list, they responded to a single probe from the examiner. While subjects did not produce the entire list of words in this task, Henry (1991b) argued that they would still need to engage in rehearsal of the entire list in order to correctly identify the position of the probed item. She found that five-year-old subjects who demonstrated a word length effect during full verbal recall tasks did not demonstrate it in the PR task. Seven-year-old subjects, on the other hand, demonstrated the word length effect in both types of tasks. These results were consistent with Henry’s (1991b) hypothesis that younger children do not rehearse, and that the word length effect in full verbal recall conditions resulted from decay during the response output. This suggests that it was during the response period, not during a period of rehearsal, that the stored words decayed. When articulation time was factored out by minimizing the amount of verbal output, the word length effect disappeared, since there was no
subvocal rehearsal to produce it. Henry (1991b) concluded that when young children demonstrate a word length effect in Full Recall (FR) tasks, the effect cannot be assumed to be resulting from the operation of rehearsal.

Questions about the application of the working memory model to children extend to its use with children with language impairments. Age and task requirements may be resulting in contradictory conclusions about whether children with language impairments have more specific difficulties in working memory, or general problems with cognitive processing. Rehearsal deficits have been reported in at least two studies of older children with language impairment (Gillam et al., 1995; Kirchner & Klatzky, 1985). Yet other studies, such as those reported by Gathercole and Baddeley (1990), have been presented as evidence of successful use of rehearsal in children with language impairment.

The present study investigated the word length effect as a measure of subvocal rehearsal in children with language impairment. Two conditions were used in order to determine whether the word length effect should be attributed to rehearsal. One task, full verbal recall of word lists, required the usual amount of verbal output. The other task, PR, substantially decreased the output requirements while maintaining the need to hold entire lists of words in short-term memory. Theoretically, subjects engaging in rehearsal should demonstrate the word length effect in both full list recall and PR tasks. Conversely, subjects not engaging in rehearsal should demonstrate the word length effect only when a full list response is required.

The empirical questions of interest were (a) whether the word length effect would be demonstrated by children with language impairment and their language and age peers in both task conditions, and (b) whether children with language impairment would demonstrate rehearsal deficits compared to their language and age peers. It was predicted that all three groups would demonstrate a word length effect in the full list recall condition. The predictions for the PR condition were determined according to the age of the subject groups. The younger subjects that served as language controls were not expected to demonstrate a word length effect in the PR condition, as they were well below the age at which rehearsal behaviors would be expected to occur. Conversely, the older subjects that served as chronological age controls were old enough to use rehearsal, and were expected to demonstrate the word length effect in both task conditions. Based on their level of language development, which was equivalent to that of children too young to rehearse, it was predicted that the language-impaired subjects would not demonstrate a word length effect in probed recall.

1. Method

1.1. Participants

Eleven children with language impairment (LI; mean age 7;0), 11 normally developing children matched for chronological age (AM; mean age 7;1), and 11
normally developing children matched for expressive language (LM; mean age 4;10) participated. The LI and LM groups each consisted of five girls and six boys. The AM group consisted of seven girls and four boys. All achieved a standard score of 85 or greater on one of two tests of nonverbal reasoning: the Columbia Mental Maturity Scale (CMMS; Burgemeister, Blum, & Lorge, 1972) or the Test of Nonverbal Intelligence (TONI; Brown, Sherbenou, & Johnsen, 1986). All of the children passed a pure-tone audiometric screening at 500, 1000, and 2000 Hz presented at 20 dB (ANSI, 1969). None demonstrated severe phonological impairments or any other physical or motor problems that would interfere with their ability to perform the experimental tasks.

The children with language impairment had been identified by their school speech-language pathologists as language impaired, as determined by a score of 1.5 standard deviations or more below the mean on at least two tests of language development. These children also performed at or below the 16th percentile for their age on the Carrow Elicited Language Inventory (CELI; Carrow, 1974).

The children in the language-matched group were selected from a preschool attended by children from a geographic and socioeconomic background similar to that of the language-impaired subjects. Language-matched children scored above the 50th percentile for their age on the CELI. These children were matched to the language-impaired group based on Developmental Syntax Scores (DSS; Lee, 1977) obtained from a 50-utterance language sample.

Each child in the age-matched group was selected from the same classroom as the language-impaired child he or she was paired with, insofar as this was possible. Two of the age-matched children were selected from a neighboring classroom. All of the age-matched children performed above the 50th percentile for their age on the CELI.

1.2. Materials

Two list-recall tasks were administered: FR and PR. Each task included a total of 32 lists (Appendix A). Half of the lists were composed of one-syllable words (short word condition), and half of three-syllable words (long word condition). Within each of the word length conditions, four list lengths (3-, 4-, 5-, and 6-word lists) were presented four times each. Thus, there were four 3-word lists of short words, four 3-word lists of long words, four 4-word lists of short words, and so forth.

The words included in the tasks were of common items that could be easily represented in line drawings. Words were placed randomly in each list, with the condition that none of the words in a given list were from the same semantic category, or possessed similar phonological characteristics (Appendix B).

The lists for each task were then recorded on audiotape at the rate of one word every two seconds. For the PR task, target words were probed from across all list positions, such that comparable numbers of words were probed from the beginning, middle, and end of the list.
1.3. Procedure

Testing was accomplished in four or five sessions of fifteen minutes to one hour in length. During the first two or three sessions, screening and matching procedures were administered. The experimental tasks were administered within one month of selection, during two separate sessions at least one day, but not more than one week, apart. All of the subjects were included in both the FR and PR conditions. The order of task presentation was counterbalanced across participants. Order of presentation was found to have no significant effect ($F(1) = 0.024, P = 0.878$).

During the first experimental session, each child was presented with a set of colored line drawings representing all of the words to be used in the tasks. The experimenter asked the child to name each picture. If the child did not produce the target word, the experimenter supplied the label and then returned to the item sometime later. Most of the children did not require such prompting; those that did were able to produce the appropriate word when asked again. In all cases, when a child failed to produce the target word, they produced a reasonable alternative based on the picture (e.g., “alligator” for “crocodile”). Once the examiner was satisfied that the child was familiar with the target words, task administration proceeded.

In both tasks, the children listened to audiotaped lists of words, and watched as a blank note card (a visual place-holder) was placed in front of them as each word was presented. In the FR condition, the child repeated back as many words as possible. In the PR condition, the examiner pointed to one of the cards and the child repeated the corresponding word. A brief training session preceded each task. Instructions and stimuli were presented via audiotape. Four practice lists, one of each list length, were provided. These lists were composed of two-syllable words. During the training session, the examiner demonstrated the procedures as the instructions were played on the tape. Following the completion of the task, each child was allowed to select a small prize (stickers, crayons, or small toys).

1.4. Scoring

Children’s responses were recorded on audiotape. A correct response in the FR condition consisted of production of all of the target words in a list. In the PR condition, a correct response consisted of production of the probed item. When children revised their responses, the last response was used for scoring. Production of target items had to be exact in order to receive credit (i.e., “bad” for “bed” would not be acceptable). A percent correct score (number of items correct divided by four trials) was calculated for each list length by word length combination.

1.5. Reliability

A random sample of the audiotaped performance of two children from each of the subject groups was scored by an independent judge, a graduate student in
speech-language pathology. Each tape was transcribed and scored by the independent judge, and two calculations of reliability were obtained: percent agreement on transcription and percent agreement on scores. Percent agreement on transcription ranged from 92 to 95.5%, with a mean percent agreement of 96%. Differences in opinion were in all cases due to judgments on phonologically similar words, such as “pan” and “pen.” Percent agreement of scoring ranged from 99 to 100%, with a mean percent agreement of 99.5%.

1.6. Design

Within each task condition, the three experimental variables of Group, Word Length, and List Length were arranged into a 3.24 split-plot factorial with repeated measures design, with nonverbal reasoning score as a covariate. The between-subjects factor, Group, consisted of (1) children with LI, (2) normally developing children matched for expressive language level (LM), and (3) normally developing children matched for chronological age (AM). The first within-subjects factor, Word Length, consisted of (1) short words and (2) long words. The second within-subjects factor, List Length, consisted of (1) 3-word lists, (2) 4-word lists, (3) 5-word lists, and (4) 6-word lists.

Nonverbal reasoning was included as a covariate in the analysis, because even though all participants were preselected to fall within normal limits, recent studies have indicated that language-impaired children tend to achieve lower scores on average than do their normally developing peers (Nippold, 1992). The decision was supported by a significant correlation between nonverbal reasoning scores and overall memory scores ($r = 0.597$, $P < 0.001$) among the current participants. A $t$-test indicated that the mean nonverbal reasoning score for the LI group was significantly different from that of the AM group ($F = 4.37$, $P = 0.05$). A test of homogeneity of slopes resulted in a nonsignificant difference ($F(2) = 0.68$, $P = 0.514$), indicating that nonverbal reasoning scores were distributed along the same slope for all three groups. Adjustment of scores for the covariate diminished the differences between the groups primarily by increasing the LI scores and decreasing the AM scores in both task conditions.

2. Results

2.1. Full Recall

The first analysis was designed to investigate the effect of word length on the amount of material recalled during full verbal repetition of lists of words. All main effects and two-way interactions were significant, but were subsumed under a significant three-way interaction. This interaction was subsequently broken down into its component simple effects. To control for experimentwise error rate, alpha
levels for each variable were determined by dividing the overall alpha level (0.05) by the number of levels of the relevant variable. Thus the alpha level differed depending on whether the effects being examined involved Group \((z = 0.017)\), Word Length \((z = 0.025)\), or List Length \((z = 0.0125)\).

A significant simple main effect for Word Length was found in 3- and 4-word lists \((F(1, 30) = 11.08, P < 0.017)\) and \((F(1, 30) = 32.78, P < 0.017)\), respectively) in which short words were recalled more frequently than long words (Figs. 1 and 2). Within the Word Length \(\times\) List Length interaction, Word Length was significant in 3-word lists for the LI group \((F(1, 30) = 6.11, P < 0.025)\) as well as in 3- and 4-word lists for the LM group \((F(1, 30) = 7.54, P < 0.025)\) and \((F(1, 30) = 7.82, P < 0.025)\), respectively) and 4- and 5-word lists for the AM group \((F(1, 30) = 43.71, P < 0.025)\) and \((F(1, 30) = 14.93, P < 0.025)\), respectively).

As predicted, the LI group’s scores reflected a word length effect, as did those of the AM and LM groups. In addition, the children with language impairment were less able than their chronological and language age peers to reproduce longer lists.

2.2. Probed Recall

This part of the study investigated recall of word lists when only the single item probed had to be reproduced verbally. The same statistical analyses were performed as described for the FR condition. Of particular interest was whether the LI subjects and the LM controls would demonstrate a word length effect when production requirements were diminished.
The analysis resulted in a main effect for Group that approached, but did not quite reach, statistical significance ($F(2, 29) = 2.99, P > 0.05$). Significant main effects for Word Length ($F(1, 30) = 8.83, P < 0.05$) and List Length ($F(3, 90) = 31.18, P < 0.05$) were subsumed under a significant Word Length × List Length interaction ($F(3, 90) = 3.24, P < 0.05$) (Figs. 3 and 4). While Group did not interact with Word Length ($F(2, 30) = 1.34, P > 0.05$), List Length ($F(6, 90) = 0.86, P > 0.05$), or the Word Length × List Length interaction ($F(6, 90) = 0.22, P > 0.05$), the simple main effect of Word Length did not reach significance in any of the groups at any list length. However, this effect did approach significant levels for the LM group in 5-word lists ($F(1, 30) = 4.48, P = 0.043$) and for the AM group in 3-word lists ($F(1, 30) = 3.98, P = 0.055$).

An informal comparison of the group means showed that the AM group recalled the greatest number of lists, followed by the LI group, and then the LM group (Fig. 2). In recalling short word lists, the LI group’s scores fell between the other two groups; for longer words, the LI group’s performance was almost the same as the AM group. This suggests that if differences were significant, as could occur with larger numbers of subjects, these differences would be between the AM and LM groups, or perhaps both the AM and LI groups as compared to the LM group.

The patterns of performance among the three groups were much more similar in this task than in the FR task. Whereas the degree of recall demonstrated by the LI group was markedly decreased relative to both control groups in the FR task, in the PR task, where production requirements were minimized, the LI group’s recall

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**Fig. 3.** Word length effect by group in 3-word lists in Probed Recall. Abbreviations: LI, language impaired; LM, language-matched controls; AM, age-matched controls.

**Fig. 4.** Word length effect by group in 4-word lists in Probed Recall. Abbreviations: LI, language impaired; LM, language-matched controls; AM, age-matched controls.
performance was statistically indistinguishable from that of their chronological age peers.

In summary, the differences in performance that were seen among the three groups in the FR condition were not as pronounced in the PR condition. The LI children performed more like their language- and age-matched peers in PR. Furthermore, none of the groups demonstrated a statistically significant word length effect in this task condition, in contrast to the findings in the FR condition.

3. Discussion

The present study aimed to determine whether children with language impairment engage in subvocal rehearsal. The significant word length effect within each group during full recall is consistent with Gathercole and Baddeley (1990), who reported that their subjects with language disorder, along with the age and verbal control groups, displayed a word length effect in a FR task. Yet in the present study this was not interpreted as evidence of subvocal rehearsal, because in the PR task, no significant word length effect was found for any of the groups. Use of subvocal rehearsal was not supported by the results, but could also not be summarily ruled out, because there was a visible, although statistically non-significant, trend toward a word length effect for all three groups. It may be that the children in the age-matched group were still too young to be using rehearsal, or that there were too few rehearsers in the group to produce a statistically significant effect.

The only significant group differences found in this study were in the full list recall condition, where the LI group performed significantly worse than the two control groups, even after differences in nonverbal reasoning were covaried. The children with language impairment were expected to perform more poorly than their age-peers based on the fact that this result has been consistently reported in the literature. The fact that their performance was worse than that of language-matched peers is consistent with the findings of most researchers in this area (e.g., Gathercole & Baddeley, 1990; Gillam et al., 1995). Thus, the results of the FR condition support the idea that children with language impairment display less ability to recall lists of words than would be expected based on their chronological age or productive language level.

Of particular interest, though, was the lack of significant group differences when the subjects were tested under the PR method. When output requirements were reduced, and differences in nonverbal reasoning were covaried, the children with language impairment proved as capable as the control groups at recalling the list items. This suggests that whatever difficulties the children with language impairment had in performing the short-term memory tasks were more related to the requirement for full reproduction of the lists, rather than to impaired storage or rehearsal.
One possible explanation for the deficits displayed by children with language impairment has been advanced by Gillam et al. (1995). They suggested that children with language impairment have specific difficulties in maintaining in memory the temporal qualities of auditory information. While this would explain why their subjects displayed improved scores when item order and position were overlooked, it would not explain the results of the present study. In this case, subjects had to maintain item order information in the PR condition in order to respond correctly, and it was in this condition that their performance was comparable to the control groups. While other research has suggested that the recall of sequential verbal information is difficult for children with language impairment (e.g., Fazio, 1994), the current results provide at least some indirect evidence that children with language impairment are capable of extracting and maintaining the temporal aspects of auditory information in the phonological store. It is possible that children with language impairment are unable to maintain sequential information in certain more demanding tasks, such as those that require high verbal output. Gillam, Hoffman, Marler, and Wynn-Dancy (2002) discussed the fact that children with language impairment might be particularly sensitive to increasing task demands due to both top-down and bottom-up processing limitations.

It is also possible that children with language impairment perform short-term memory tasks poorly due to generally decreased speed or efficiency of processing (Kail, 1994; Lahey et al., 2001; Sininger et al., 1989). Research on developmental influences on short-term memory indicates that it is exactly processing speed and efficiency that change during development (Dempster, 1981). Other researchers have also speculated that children with language impairment might develop more slowly in terms of their ability to process information rapidly and efficiently (e.g., Curtiss & Tallal, 1991; Montgomery, 2002; Paul & Alforde, 1993). Thus, rather than having structural defects in working memory, children with language impairment may have difficulty achieving the efficient use of short-term memory processes. Decreased processing speed could have affected accuracy of performance in the FR condition of this study, while leaving performance in the PR condition unimpaired, because in full recall all of the items had to be accessed and produced. A slowed rate of access would have allowed more time for memory traces to decay in the FR condition than in PR.

The decreased processing speed explanation illustrates how short-term memory difficulties could have an effect on language comprehension and production. With respect to comprehension, Sininger et al. (1989) noted that a failure to rapidly process “the incoming speech signal, and/or its structural and meaningful implications” could result in a distortion or loss of information (p. 296). Leonard, McGregor, and Allen (1992) also suggested that the processing demands of making difficult discriminations could detract from resources necessary for performing other operations. Whether the processes involved have to do with discriminating or assigning meaning to speech signals, a diminished processing rate could clearly affect comprehension.
The fact that many children with language impairment display even greater deficits in production than in comprehension could also be explained if their processing for output purposes (e.g., memory scanning or response planning) is especially affected. Recent studies of the capabilities of children with language impairment in domains other than short term memory have suggested this possibility. Rescorla and Goossens (1992) reported that their expressive specific language-impaired subjects were delayed in pretend play as well as language. They suggested that these children “might have some deficiency in the fluent, rapid, and spontaneous retrieval and encoding of two forms of stored symbolic representations, namely lexical entries for semantic referents in the case of language and event representations, scripts, or schemes in the case of play” (p. 1299). Connell and Stone (1992) also suggested that their subjects with specific language impairment benefited from an imitation-learning condition to a greater degree than normally developing children because they had a particular difficulty in accessing, rather than learning, the stimulus items. In fact, Curtiss and Tallal (1991) suggested that language learning mechanisms may be relatively unimpaired, and that the disorder might be better described as a processing impairment. In the present study, the fact that the children with language impairment performed like their age peers when output requirements were decreased suggests that output processing problems play a significant role in their short-term memory deficits.

The processing limitation explanation also has some potential for clinical application. Evaluation of processing limitations may prove to be a useful tool in early identification and diagnosis of language impairment (Ellis Weismer & Evans, 2002; Ellis Weismer et al., 1999; Montgomery, 2002). Furthermore, some research has indicated that processing efficiency can be increased as a result of practice, by increasing automaticity (Samuels, Dahl, & Archwamety, 1975). This possibility is indirectly supported by Connell and Stone’s (1992) finding that children with specific language impairment were better able to produce an invented morpheme following imitation training than following modeling alone. They noted that “the requirement to imitate the stimulus could serve . . . to refine the phonological representation and to provide practice accessing it” (p. 851). Other researchers have also noted that it is at least theoretically possible that practice could make processing more automatic, so that it would require less capacity (Kirchner & Klatzky, 1985). Gillam and van Kleeck (1996) argued persuasively that working memory relates to a wide variety of language abilities, all of which might improve given intervention in working memory.

4. Conclusion

The results of this study generally support the view that a significant component of language impairment is related to slower and/or less efficient processing of
verbal information. Evidence is emerging that it is worthwhile to examine the ways in which children process verbal information, both for diagnostic and therapeutic purposes.

Questions remain as to the most appropriate methods for understanding processing limitations. Investigations of children’s working memory performance make it clear that the Baddeley working memory model must be carefully examined when applied to children, particularly in any attempts to understand the nature of working memory difficulties of children with SLI. In a population noted for decreased verbal output, the potential impact of output factors on task performance should be carefully evaluated.

While the exact nature of the relationship between working memory, language development, and language disorders is not precisely understood, continued research into these areas should prove an important part of our understanding of the mechanisms of human language learning. Clues as to the nature of language impairment and effective treatment strategies could also be found, improving our ability to diagnose and treat these children.

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Appendix A. Continuing education

1. In the working memory model developed by Baddeley and coworkers, the term, “phonological loop” refers to
   a. the phonological processes involved in normal language development.
   b. the process of recirculating auditory information for temporary storage.
   c. the process of attending to speech or speech-like information.
   d. the area of the brain responsible for storing phonological information.
   e. the ability to remember phonological rules.

2. A person will most likely find it easier to recall a list like “bat, key, cup, man, duck” than one like “hamburger, crocodile, metaphor, Halloween, tuition.” This is known as
   a. the primacy effect.
   b. the latency effect.
   c. the rehearsal effect.
3. Researchers have consistently found that children with language impairment
   a. perform worse on short-term memory tasks than normally developing
      children matched for language ability.
   b. require an average of four repetitions before repeating a list of three
      words correctly.
   c. have difficulty maintaining sequential, temporal qualities of auditory
      information.
   d. demonstrate an increased rate of processing speed, which interferes
      with accuracy.
   e. typically score just as well as normally developing children of the same
      age on tests of nonverbal intelligence.

4. In this study, children with language impairment demonstrated signifi-
   cantly worse recall of word lists than age- and language-matched peers
   under which experimental condition?
   a. Probed recall
   b. Full recall
   c. Group recall
   d. Delayed recall
   e. Rapid recall

5. By better understanding how working memory functions in children with
   language impairment, researchers and clinicians hope to
   a. increase the number of children identified with language impairments
      in infancy.
   b. eliminate the processing deficits that underlie language impairment.
   c. develop useful methods for diagnosing and treating language
      disorders.
   d. redefine specific language impairment as a processing impairment.
   e. find evidence that language ability is critical in the development of
      memory skills.

Appendix B. Sample stimulus lists

Full Recall:
   1. Tree, pig, spoon
   2. Crocodile, skeleton, popsicle, radio

Probed Recall:
   1. Pan, book, frog (probe: frog)
   2. Mosquito, strawberry, newspaper, telephone (probe: newspaper)
### Appendix C. Stimulus words

<table>
<thead>
<tr>
<th>One-syllable</th>
<th>Three-syllable</th>
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<tbody>
<tr>
<td>Bat</td>
<td>Banana</td>
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<td>Bed</td>
<td>Basketball</td>
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<tr>
<td>Bell</td>
<td>Butterfly</td>
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<tr>
<td>Belt</td>
<td>Crocodile</td>
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<tr>
<td>Book</td>
<td>Dinosaur</td>
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<tr>
<td>Cake</td>
<td>Elephant</td>
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<td>Hamburger</td>
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<td>McDonalds</td>
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<td>Deer</td>
<td>Mosquito</td>
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<td>Door</td>
<td>Newspaper</td>
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<td>Egg</td>
<td>Pajamas</td>
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### References


