This study investigated verbal working memory capacity in children with specific language impairment (SLI). The task employed in this study was the Competing Language Processing Task (CLPT) developed by Gaulin and Campbell (1994). A total of 40 school-age children participated in this investigation, including 20 with SLI and 20 normal language (NL) age-matched controls. Results indicated that the SLI and NL groups performed similarly in terms of true/false comprehension items, but that the children with SLI evidenced significantly poorer word recall than the NL controls, even when differences in nonverbal cognitive scores were statistically controlled. Distinct patterns of word-recall errors were observed for the SLI and NL groups, as well as different patterns of associations between CLPT word recall and performance on nonverbal cognitive and language measures. The findings are interpreted within the framework of a limited-capacity model of language processing.

KEY WORDS: language disorders, working memory, limited processing capacity, memory span

Various models of language processing have been proposed that incorporate the notion of a limited-capacity system (Baddeley, 1986, 1996; Bloom, 1993; Bock, 1982; Gathercole & Baddeley, 1993; Just & Carpenter, 1992). The major premise of these various limited-capacity models is that the human information processing system has a limited pool of operational resources available to perform computations and when demands exceed available resources, the processing and storage of linguistic information is degraded. The combination of processing and storage functions is referred to as working memory (Anderson, 1983; Baddeley, 1986, 1996, 1998; Cantor & Engle, 1993; Cowan, 1988, 1995; Just & Carpenter, 1992; Just, Carpenter, & Keller, 1996). According to this view, success in comprehending and producing language is dependent upon the ability to actively maintain and integrate linguistic material in working memory, and trade-offs are thought to occur within and across language domains as demands reach the limits of resources.

Evidence of linguistic interactions and trade-offs has been reported within the language-acquisition literature and from experimental studies with adults. For instance, semantic complexity has been found to be higher in shorter utterances than longer utterances during early stages of development (Bloom, Lightbown, & Hood, 1975), and increased naming errors have been observed to co-occur with rapid growth in productive vocabulary and increased rates of speaking in young children (Gerschkoff-Stowe & Smith, 1997). Investigations with adults have shown
that speed and accuracy of linguistic processing declines as cognitive load is increased. Some factors that have been observed to affect linguistic processing include constraints on processing time (Miyake, Carpenter, & Just, 1994), degree of lexical ambiguity (MacDonald, Just, & Carpenter, 1992), and degree of syntactic complexity or ambiguity (Carpenter & Just, 1989).

Direct associations between working-memory capacity and language abilities have been demonstrated for both children and adults. Investigations have indicated an association between phonological working memory as measured by a nonword repetition task and vocabulary development in young, typically developing children (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1990b, 1993; Gathercole, Willis, Emslie, & Baddeley, 1992). Phonological memory has also been shown to be significantly related to acquired vocabulary at age 5 years and predictive of children’s ability to learn new words (Michas & Henry, 1994). School-age children’s performance on working-memory measures has been found to be significantly correlated with various intelligence and achievement measures, including reading recognition and comprehension (Swanson, 1996) and with spoken-language comprehension (Gaulin & Campbell, 1994; Swanson, 1996). Working-memory capacity has been shown to predict a number of verbal abilities in adults, including reading comprehension levels, verbal Scholastic Aptitude Test (SAT) scores, comprehension of syntactically complex sentences, understanding of ambiguous passages, the ability to learn the meanings of novel words on the basis of context, and the ability to draw inferences (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Carpenter, Miyake, & Just, 1994; Cochrane & Davis, 1987; Daneman & Carpenter, 1980, 1983; Daneman & Green, 1986; King & Just, 1991; Masson & Miller, 1983; Turner & Engle, 1989).

Two models of working memory have been particularly influential in developmental and/or disabilities research: those of Baddeley and colleagues (Baddeley, 1986; Gathercole & Baddeley, 1993) and J ust, Carpenter, and colleagues (Daneman & Carpenter, 1980; J ust & Carpenter, 1992; MacDonald, J ust, & Carpenter, 1992). These models differ in their conception of working memory and in the paradigms assumed to assess this construct. Baddeley’s model posits that working memory consists of a central executive component and modality-specific storage buffers, including the phonological loop involved in language processing and retention. Within this framework, the emphasis has been on the role of the phonological loop in immediate recall of spoken language as assessed by a nonword repetition paradigm. J ust and Carpenter’s model focuses on a global set of resources supporting language computations (including lexical and syntactic processing and storage) rather than centering on the phonological loop. This limited-capacity model of reading comprehension has been extended to auditory-language processing, with investigators employing reading- and listening-span measures of working-memory capacity. Although studies have challenged specific aspects of both Baddeley’s model (Jones & Macken, 1995; LeCompte & Shaibe, 1997; Neath, Suprenant, & LeCompte, 1998) and Just and Carpenter’s capacity theory of comprehension, particularly with regard to explanations of sentence processing by adults with aphasia (Martin, 1995; Waters & Caplan, 1996), there are numerous studies supporting each model (cf. Baddeley, 1998; Gathercole & Baddeley, 1993; Haarmann, J ust, & Carpenter, 1997; J ust & Carpenter, 1992; Just, Carpenter, & Keller, 1996; Miyake, Carpenter, & J ust, 1995).

A number of researchers have proposed that children with specific language impairment (SLI) have particular limitations in their capacity to process and store information (Bishop, 1992; Gathercole & Baddeley, 1990a, 1993; Ellis Weismer, 1996; Lahey & Bloom, 1994; Leonard, 1994; Montgomery, 1995, 1996). Some of these claims stem from inferences drawn from performance on various verbal tasks and nonverbal reasoning tasks rather than direct assessment using measures designed to evaluate working-memory capabilities. Other investigations have employed nonword repetition tasks (Bishop, North, & Donlan, 1996; Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Gathercole & Baddeley, 1990a; Montgomery, 1995), a paradigm that has been used extensively by Baddeley and colleagues as a measure of phonological working memory. Gathercole and Baddeley (1990a) found that children with SLI demonstrated significantly poorer phonological working memory than normal-language controls matched on nonverbal cognition or verbal skills. However, van der Lely and Howard (1993) argued that their findings from two different measures of immediate recall did not support this contention. A debate ensued in the literature, centering around the use of varying subject-selection criteria for SLI and differences in the tasks purported to measure working/short-term memory (Gathercole & Baddeley, 1995; Howard & van der Lely, 1995). A subsequent study by Montgomery (1995) replicated the findings of Gathercole and Baddeley (1990a) and similarly concluded that children with SLI have reduced phonological storage capacity. Bishop et al. (1996) have suggested on the basis of a genetic study of twins that deficits in nonword repetition provide a phenotypic marker of developmental language impairment.

Despite the widespread use of nonword repetition as a measure of phonological working memory, questions have been raised about the cognitive processes underlying this task, particularly about the extent to which performance on these tasks is constrained by phonological working memory versus long-term lexical knowledge (Dollaghan, Biber, & Campbell, 1993, 1995; Gathercole,
Swanson (1993) concluded that children with learning disabilities have a generalized deficit in working-memory abilities such that they have difficulty retaining information in memory while simultaneously processing that same material or other information.

Gaulin and Campbell (1994) adapted the Daneman and Carpenter sentence-span task for use with younger elementary-school-age children to measure developmental changes in working memory, using sentences 3 words in length. On their version of this task, referred to as the Competing Language Processing Task (CLPT), Gaulin and Campbell found significant age-related changes in word-recall performance for children 6 through 10 years of age. Significant moderate correlations were noted between word recall on the CLPT and measures of verbal memory (digit span and word sequences); but of potentially greater interest for the current study is the fact that the strongest correlation observed was between CLPT word recall and receptive-language abilities. In a subsequent study, Campbell, Dollaghan, Needleman, and Janosky (1997) examined the performance of typically developing children from minority and majority backgrounds on the CLPT and other processing-dependent measures relative to their performance on knowledge-dependent measures that relied heavily on world experience and vocabulary knowledge. They found that minority subjects obtained significantly lower scores on the knowledge-dependent measures than the majority children, but that the performance of the groups did not differ on any of the processing measures. Campbell et al. interpreted these results as suggesting that processing measures such as the CLPT may be useful in providing non-culturally biased assessments of children with language disorders.

Adaptations of the Daneman and Carpenter span task have been devised to investigate working-memory deficits in children with learning disabilities (Swanson, 1993; Swanson, Cochran, & Ewers, 1989) as well as development of working memory in typically developing children (Gaulin & Campbell, 1994). Swanson and colleagues' (1989) sentence-span task, developed for middle-school-age children (11- and 13-year-olds), requires that children answer questions about sets of unrelated sentences, 7–10 words in length, while holding in mind the last word of each sentence. Findings indicated that skilled readers had significantly higher sentence span scores than poor readers. Using a diverse array of verbal and visual-spatial working-memory measures, Swanson (1993) concluded that children with learning disabilities have a generalized deficit in working-memory abilities such that they have difficulty retaining information in memory while simultaneously processing that same material or other information.
strong, positive relationship with children’s language abilities and perhaps with their nonverbal cognitive skills as well.

**Method**

**Participants**

Forty school-age children participated in this investigation, including 20 children with SLI and 20 agemates with normal language development. The SLI group had a mean chronological age (CA) of 7;8 (years;months/range = 5;8-9;7) and consisted of 11 boys and 9 girls. The NL control group had a mean age of 7;9 (range = 6;2-9;4) and included 8 boys and 12 girls. Maternal educational level was used as an index of socioeconomic status (SES) to compare the groups, because research indicates that this variable is a significant predictor of children’s language skills (Chapman, Schwartz, & Kay-Raining Bird, 1991). The mean number of years of maternal education was 15 (SD = 4, range =10-22) for the SLI group and 16 (SD = 3, range = 12-21) for the NL controls. All children were monolingual, native English speakers and were primarily from the majority culture; 34 Caucasian and 6 African American (AA) children participated in the study (SLI group, 5 AA; NL group, 1 AA).

All participants exhibited normal-range nonverbal cognitive abilities (i.e., Age Deviation Scores, ADS, of at least 85) on the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972) and passed hearing screenings (per ASHA guidelines, 1990) that were administered at the time of testing. None of the children evidenced physical, motor, or emotional handicaps according to parent report or school records. Children who served as normal language controls had no history of speech, language, or hearing problems or any other exceptional educational needs based on school records and background information supplied by the parents. Children in the experimental group had previously been diagnosed by a certified speech-language clinician as having a language impairment and were receiving clinical services in their schools in Madison, WI, and the surrounding area. Five of the children in the SLI group had also been identified as having a learning disability or were receiving special programming for reading difficulties. Grade levels of the participants ranged from kindergarten to third grade for the NL children and kindergarten to fourth grade for children with SLI. (A number of children were in ungraded classrooms that correspond to several grade levels in traditional classrooms, e.g., grades 3-4.)

Four language measures were used to classify the children for this study. They included (1) Test of Auditory Comprehension of Language–Revised (TACL-R; Carrow-Woolfolk, 1985); (2) Token Test for Children (DiSimoni, 1978); (3) Mean Length of Utterance (MLU) in morphemes derived from 12-minute, narrative language samples and analyzed using Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1996); and (4) additional Productive Language Features based on the SALT analyses, which included omission of bound morphemes, omitted words, word errors, utterances with pauses, different word roots, and/or type token ratio. Because MLU is a less sensitive index at more advanced levels of language development, these features of productive language abilities analyzed by SALT also were examined in cases where MLU fell within the normal range. Values for MLU and Productive Language Features were compared with the SALT Reference Data Base norms collected on Madison area children using SALT Profiler.

Children were included within the SLI group if they scored at least one standard deviation (SD) below the mean on the TACL-R, Token, and/or MLU (or at least 1 SD beyond the mean on two or more SALT Productive Language Features), whereas those in the control group scored above –1 SD on all measures. Results of t-test analyses indicated that the SLI group scored significantly poorer than the NL control group on MLU [t(38) = –5.19, p <.001] and on both of the receptive language measures: the Token [t(38) = –4.04, p <.001] and the TACL-R [t(38) = –4.23, p <.001]. Characteristics of the groups are summarized in Table 1.

Within the SLI group, 12 of the 20 children demonstrated a mix of receptive/expressive deficits, whereas 8 exhibited only expressive deficits. For the 12 children exhibiting both receptive and expressive delays, 9 scored at least –1 SD on the TACL-R, 8 on the Token, 6 on MLU; 6 scored 1 SD or more beyond the mean on two or more SALT Productive Language Features. For the 8 children with expressive deficits, 6 fell below the criteria for MLU, and 2 qualified on the basis of Productive Language Features from the SALT analyses.

**Procedure**

Children in this study were participating in a larger investigation of linguistic processing, which included administration of several experimental tasks not reported here. The experimental (sentence-span) task and assessment measures pertinent to this study were completed within two sessions, each lasting approximately one hour. Testing was conducted at the Language Processes Laboratory in the Waisman Center on the University of Wisconsin–Madison campus.

The experimental task employed in this study was the Competing Language Processing Task (CLPT), developed by Gaulin and Campbell (1994) to assess verbal working memory in school-age children. As described
Table 1. Summary of participant characteristics for the group with specific language impairment (SU) and the normal language (NL) age-matched control group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>SU Group (n = 20)</th>
<th>NL Group (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic age (months)</td>
<td>M = 93, SD = 13</td>
<td>M = 95, SD = 13</td>
</tr>
<tr>
<td>Columbia* Standard Score</td>
<td>104 (9)</td>
<td>110 (7)</td>
</tr>
<tr>
<td>TACL-R** Standard Score</td>
<td>41 (9)</td>
<td>52 (7)</td>
</tr>
<tr>
<td>Token** Standard Score</td>
<td>497 (5)</td>
<td>502 (3)</td>
</tr>
<tr>
<td>SALT MLI d</td>
<td>6.5 (1.4)</td>
<td>8.8 (1.3)</td>
</tr>
</tbody>
</table>

*ADS refers to Age Deviation Scores, which are standard scores from the Columbia Mental Maturity Scale based on a mean of 100 and standard deviation of 16.

**T-tests between group means were significant (p < .05)

Previously, this measure is an adaptation of a sentence-span task by Daneman and Carpenter (1980) designed to evaluate adults' verbal memory span. In the version developed for children, groups of 1 to 6 short sentences are presented and children must demonstrate comprehension by responding Yes or No to each statement. Concurrently, children are asked to recall the last word of each sentence after all of the sentences in a group have been presented. Thus, the truth of each statement must be determined while the last word of each sentence is held in working memory. Like the sentence-span task, they were provided with feedback on the practice items. If child correctly repeated the last word in each practice sentence, the examiner responded "That's just what I want you to do." If children did not repeat the last word or indicated that they did not understand the task, they were asked to repeat the entire first sentence (which was played as needed). Then they were asked to tell the examiner the last word in that sentence. These prompts were repeated for the second sentence in the first group of practice statements. At this point, all children were able to correctly respond with the last words of the initial group of practice sentences. The examiner then proceeded to the second group of practice sentences. If a child demonstrated understanding of the task by correctly answering Yes and No and repeated the last word for at least one of the two sentences, the test items were administered. No children were excluded for failing to meet this criterion.

Stimulus sentences, practice items, and instructions had been tape recorded and were presented under earphones. The same recorded stimuli used in the Gaulin and Campbell (1994) study were used in the present investigation. Instructions and test stimuli had been recorded by a female speaker at normal rate (approximately 160 wpm). The duration of each stimulus sentence was approximately 2 s and was followed by a 3- to 4-s pause during which the child could respond Yes or No to each statement. At the end of each group of sentences within a particular level the child heard the recorded prompt, "What was the last word of each sentence?" The tape recorder was paused at those points to allow adequate time for responding. Children's responses were scored on-line and audiotape recorded for the purposes of establishing scoring agreement.

Before beginning the task, children were given the following live-voice instructions in addition to the recorded instructions:

Next, we'll wear earphones and listen to a tape. The person on the tape will tell you what to do, but I'll tell you a little bit first. You'll hear groups of sentences. After each sentence, tell me YES if it is true or NO if it is false. The person on the tape will ask you to tell me the last word in each sentence in the group. As we go, it gets harder because there are more and more sentences in the groups, but just do your best. We'll do some practice ones so you'll get an idea of what the sentences are like.

Children were provided with feedback on the practice items. If child correctly repeated the last word in each practice sentence, the examiner responded "That's just what I want you to do." If children did not repeat the last word or indicated that they did not understand the task, they were asked to repeat the entire first sentence (which was replayed as needed). Then they were asked to tell the examiner the last word in that sentence. These prompts were repeated for the second sentence in the first group of practice statements. At this point, all children were able to correctly respond with the last words of the initial group of practice sentences. The examiner then proceeded to the second group of practice sentences. If a child demonstrated understanding of the task by correctly answering Yes and No and repeated the last word for at least one of the two sentences, the test items were administered. No children were excluded for failing to meet this criterion.
Scoring and Interrater Agreement

Responses were scored as correct or incorrect for both the True/False and Word Recall components of the CLPT. The sequence of word recall did not have to match that of sentence presentation; that is, responses were scored as correct if the child produced the last word of sentences within the target group regardless of whether the order of recall corresponded to that in which the sentences had been presented. On the Word Recall portion, incorrect responses were further categorized as No Response (NR) or one of several error types. Error types included: (a) Primacy Error: A response was scored as a primacy error if the child recalled the first word of a sentence within the group of sentences presented at that specific level. (b) Medial Error: Medial errors involved recall of the middle word (verb) in a sentence within the group of sentences presented at each level. (c) Within Set Repetition: A response was scored as a within set repetition if the child recalled the same target word twice in the same group of sentences. (d) Target Intrusions: Errors coded as target intrusions were those in which the child recalled a target word from any prior group or level (whether they had previously recalled that particular target word or not). (e) Semantic Substitutions: Semantic substitutions involved the recall of words that were semantically related to the target, including antonyms (e.g., big for the target small). (f) Other: Errors that did not fit within any of the categories were designated as “other.” These involved words that had not been presented in any of the stimulus sentences and did not appear to be semantically related to target words.

Ten percent of the total responses on the CLPT (half from the SLI group and half from the NL control group) were randomly selected for re-analysis from the audiorecords. There was 100% agreement between two independent judgments for both the True/False and Word Recall components of the CLPT (168 agreements/168 judgments). Re-analysis of the entire set of error responses indicated 94% agreement (96 agreements/102 judgments) in coding categories of errors.

Results

Overall Task Performance

Table 2 presents group means and standard deviations for the True/False and Word Recall components of the CLPT. All children exhibited high levels of accuracy on the True/False comprehension items, such that there was no significant difference (using an alpha level of .05) between the performance of the SLI group and the NL control group for this aspect of the task (t(38) = –1.39, p = .17). However, the children with SLI demonstrated significantly poorer word recall performance than the NL controls (t(38) = –5.01, p < .05). The mean word-recall score for the group with SLI fell 2 standard deviations below the mean for 8-year-olds based on the norms obtained with typically developing children that were reported by Gaulin and Campbell (1994). On the other hand, the word-recall performance of the NL group in the current study was quite comparable to that of Gaulin and Campbell’s normative sample (i.e., M = 60.2, SD = 13.0 compared to M = 60.4, SD = 8.7). Although there were slight differences in the groups’ SES level and racial/ethnic composition, no differences in word-recall performance were observed on the basis of ethnic/racial diversity for the 6 African American (M = 42.065, SD = 13.77) and 14 Caucasian children with SLI (M = 38.43, SD = 13.22). These findings are consistent with prior research that indicates that minority children perform similarly to those from the majority culture on the CLPT (Campbell et al., 1997).

Because the groups differed significantly with respect to nonverbal cognitive abilities, an analysis of covariance (ANCOVA) was conducted in which Group (SLI, NL) was the between-subjects variable, Columbia Age Deviation Score (ADS) was the covariate, and Word Recall score was the dependent variable. In order to test the assumption of linear and parallel regression lines, a general linear model approach was used in which the interaction term was included within the model. The Group × Columbia interaction was not significant [F (1, 36) = .268, p = .608]; therefore, the standard, constant slopes model was used for the ANCOVA. The ANCOVA revealed a significant Group difference in Word Recall, after controlling for the potential confound of nonverbal cognitive level (Columbia scores) [F (1, 37) = 17.605, p < .05, η² = .322].

Error Analysis for Word Recall

An analysis of incorrect responses on the Word Recall component of the CLPT revealed no significant difference in the percentage of No Responses [t (38) = –1.84,
between the SLI group (M = 86.6, SD = 10.6) and the NL group (M = 91.85, SD = 6.79), though there was a tendency for the overt errors (instead of No Response) than the control group. An error analysis for word-recall responses was completed to determine if the nature of the overt errors was similar across groups. The two most frequent categories of errors were Primacy and Target Intrusions for both groups, but the distribution of these errors differed for the two groups. For the SLI group, the most frequent category of errors was Primacy (51%), followed by Target Intrusions (29%). This pattern was switched for the NL control group, with Primacy errors being less frequent (36%) than Target Intrusions (50%). Medial errors (SLI = 4%, NL = 3%) and Semantic Substitutions (SLI = 7%, NL = 10%) were relatively low frequency and similar for both groups. Two of the categories, Within Set Repetition and Other, were low frequency for the SLI group (1% and 7%, respectively), but did not occur in the control-group responses.

Individual patterns of errors were then compared to group error patterns. Fifteen of the 20 NL control children demonstrated overt errors; of these 15, 8 followed the group pattern in terms of Target Intrusion errors’ being the most frequent. For the SLI group, 18 out of 20 children exhibited overt errors, but only 6 children followed the group pattern of Primacy errors as the category in which most errors occurred. Thus, a few children were heavily contributing to the overall pattern for the SLI group. These children were among the youngest children in the SLI group; similarly, Primacy errors within the NL group were observed more often for the younger rather than the older children. Target Intrusions errors, on the other hand, were distributed across the age span for both groups.

**Correlation With Cognitive and Language Measures**

The relationship between word-recall performance on the CLPT and performance on the cognitive and language measures was examined using bivariate Pearson correlations. Correlations between each pair of variables was significant (rs > .45, p < .05) when the sample was considered as a whole, apparently reflecting the group differences revealed by the ANOVA findings (i.e., there was an overall association between higher performance on language and cognitive measures and higher word-recall scores). When the correlations were examined separately for the two groups, however, different patterns of association emerged. Summaries of the correlations for the SLI group and the NL control group are presented in Table 3. For the children with SLI, nonverbal cognition (Columbia ADS) was significantly correlated with word recall on the CLPT (r = .529, p < .05), and the correlation between MLU and word recall approached significance (r = .362, p = .059). Language comprehension scores on the TACL-R were significantly correlated with CLPT word recall for the NL controls (r = .51, p < .05). As was the case for the SLI group, the correlation between MLU and CLPT word recall approached, but did not reach, statistical significance (r = .365, p = .057).

**Discussion**

The first research question addressed by this study pertained to group differences on the CLPT for the children with SLI compared to those with normal language abilities. As expected, both the NL control group and SLI group performed at high levels of accuracy on the True/False comprehension portion of the task (97.5% and 96%, respectively). This is consistent with the results of Gaulin and Campbell (1994), who found that children at all ages (6 through 12 years) performed at high levels of accuracy (97.7% to 99.3%) on the True/False component of the CLPT. The stimulus sentences on the CLPT are designed to be easily understood by children as young as 6 years of age (cf. Gaulin & Campbell, 1994); therefore, even these school-age (M = 7;8) children with SLI were demonstrating success at this aspect of the task. Although the groups were similar in their ability to comprehend the True/False statements, the SLI

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<tr>
<td>1 CLPT WR</td>
<td>—</td>
<td>2 Columbiaa</td>
<td>.529*</td>
<td>265</td>
</tr>
<tr>
<td>2 Columbiaa</td>
<td>.362 / .365</td>
<td>.300</td>
<td>.026</td>
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<td>.362 / .365</td>
<td>.300</td>
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<tr>
<td>4 TACL-Rc</td>
<td>-.096 / .510*</td>
<td>.301 / .303</td>
<td>-.024 / .226</td>
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<td>5 Tokend</td>
<td>.112 / .264</td>
<td>.180 / .149</td>
<td>.191 / .292</td>
<td>.118 / .280</td>
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*aColumbia Mental Maturity Scale. bMean Length of Utterance. cTest of Auditory Comprehension of Language–Revised. dToken Test for Children.

*p < .05
group evidenced significantly lower word-recall scores than the NL group. There was a clear dissociation between the performance of children with SLI on the comprehension component of the CLPT and the word-recall portion \( (r = .17) \), which was unlike that of the NL control group where performance was significantly correlated on the two aspects of the task \( (r = .52, p < .05) \). When nonverbal cognitive level was controlled, there was still a significant difference between groups in word recall—that is, differences in cognitive abilities were not accounting for the group effects.

The finding that children with SLI exhibited significantly poorer verbal working-memory spans than their NL peers, as evidenced by their word-recall performance, supports claims of processing-capacity-limitation accounts of SLI (e.g., Ellis Weismer, 1996; Leonard, 1994). Findings from the sentence-span measure of working memory used in the present study are in agreement with the results from studies that have used nonword repetition tasks (e.g., Gathercole & Baddeley, 1990a; Montgomery, 1995); that is, children with SLI demonstrate deficits on both types of measures relative to children with normal language abilities. These results are also consistent with preliminary findings by Ellis Weismer and Elin Thordardottir (1998) involving an independent sample of children with SLI who demonstrated restrictions in verbal working memory relative to age-matched controls on three different measures, including the CLPT. Furthermore, these findings are consistent with those of Swanson (1993), indicating that older children with learning disabilities demonstrate significantly poorer working-memory abilities than typically developing agemates across a range of different measures.

The second question posed by this investigation was whether the SLI and control groups displayed similar error patterns on the CLPT. The error-analysis findings indicated that there was a nonsignificant trend for the SLI group to exhibit a higher proportion of overt errors than No Responses compared to the NL group; this may have related to the occurrence of prompting to respond. Anecdotal evidence from notes taken during testing suggested that some of the children with SLI took a relatively long time to respond, and the examiner would query them to determine if they were finished answering or could recall any more words. On the surface, one might argue that Primacy and Target Intrusion errors indicate that children did not understand the task; however, all children were able to complete the practice items appropriately, and both groups performed well above chance level on this recall task (40% and 60% accuracy for the SLI and NL group, respectively). Alternatively, these types of errors suggest an inability to inhibit lexical information within the task that is not the focus of the current search and retrieval operations. One could speculate that Primacy errors involve confusions with material that is currently activated and the focus of attention in working memory, whereas Target Intrusions from prior groups or levels were more likely to recall the initial (rather than final) word within a group of sentences that they had most recently heard. On the other hand, final word targets from prior groups or levels were more likely to interfere with correct word recall for NL controls, indicating that they were able to hold target words from prior sets in long-term memory. It is also important to note that there is a confound of topic and/or grammatical category with order for recall. This may suggest yet another interpretation of this pattern; that is, the first words of sentences are all topics/subjects, whereas the final words represent various grammatical categories. Children with SLI may have resorted to recounting the gist (topic) of the sentences when they were unable to recall the final word.

Relatively low-frequency error types that occurred in both groups included Medial errors and Semantic Substitutions. The Medial errors can be viewed similarly to the Primacy errors in that they suggest interference with currently activated material in working memory (lexical items within the stimulus sentences) and an inability to appropriately parse the final word from the rest of the sentence for recall. Semantic substitutions reflect activation of related propositions (lexical nodes) during encoding and/or retrieval. Error patterns that occurred infrequently in the SLI group but did not occur in the NL group responses included the categories of Within Set Repetitions and Other. Within Set Repetitions could reflect a perseverative-type response pattern characteristic of some children with learning disabilities—an inability to remember that a particular word had already been listed—or it might reflect the increased prompting for the children with SLI, noted previously. Error responses that were judged as Other had no apparent relationship to the target word or sentence stimuli. These may reflect off-task behavior, "mis-remembering" of target words, or faulty semantic networks.

In summary, there is some suggestion of qualitatively different error patterns between the groups, in that two low-frequency categories of errors exhibited by the SLI group were not observed for the NL group and the most frequent pattern of error response was reversed. However, this conclusion must be qualified by the fact that there was considerable individual variation in word-recall error patterns.

The third issue addressed by this study related to the association between CLPT performance, nonverbal cognition, and language skills. The results of this investigation are consistent with prior research that has
demonstrated a relationship between working-memory capacity and language performance in that an association was revealed between children's language proficiency and word-recall performance. Significant correlations (r = .51) were found between language-comprehension abilities (as measured by the TACL-R) and CLPT word-recall scores for the NL control group in this study. These results are in agreement with those of Gaulin and Campbell (1994), who found that receptive language knowledge (Peabody Picture Vocabulary Test–Revised, PPVT-R, Dunn & Dunn, 1981) was significantly correlated (r = .63) with CLPT word recall for typically developing school-age children. Similarly, Swanson (1996) reported that receptive language (PPVT-R) scores were significantly correlated (r = .55) with performance on the adaptation of the sentence span task that he and his colleagues developed for somewhat older children (Swanson et al., 1989). A modest association (r = .36), which did not reach statistical significance in our relatively small sample investigation, was observed between MLU and CLPT word recall for both the NL and SLI groups. Prior developmental studies of the relationship between working memory and language abilities have not included expressive-language measures. It is possible that stronger correlations would be found between working memory and a measure of productive vocabulary rather than an index of productive grammatical skills (i.e., MLU) because the simple sentence constructions on the CLPT place few demands on the syntactic abilities of the children.

Contrary to the pattern observed for the NL group, working-memory capacity for the SLI group was most strongly correlated (r = .53) with nonverbal cognition (Columbia scores) instead of language-comprehension abilities. Although the NL group in the present study did not demonstrate a relation between nonverbal cognitive skills and verbal working-memory abilities, prior research has found typically developing children's intelligence (as measured by the Kaufman Assessment Battery for Children, Kaufman & Kaufman, 1983) to be significantly correlated with composite scores on verbal and visual-spatial measures of working memory (Swanson, 1996). There has been considerable debate as to whether the findings of associations between working-memory capacity and language performance or other problem-solving abilities in adults can best be interpreted within a task/domain-specific model (Daneman & Carpenter, 1980; Daneman & Tardif, 1987; Just & Carpenter, 1992) or a general-capacity model (Cantor & Engle, 1993; Engle, Cantor, & Carullo, 1992; Salthouse, Mitchell, Skovronek, & Babcock, 1989; Turner & Engle, 1989). This issue also has been debated with respect to developmental investigations of normally developing children and those with learning disabilities (Fletcher, 1985; Siegel & Ryan, 1989; Swanson, 1993, 1996; Swanson et al., 1989). Fletcher (1985) reported that children with reading disabilities scored lower on verbal memory tasks, whereas those with math disabilities scored lower on a visual-spatial memory task. However, Swanson et al. (1989) found that poor readers performed significantly worse than skilled readers on a concurrent memory task across both verbal and nonverbal conditions. In a subsequent study, Swanson (1993) reported that learning disability subgroups, those with reading compared to math disabilities, could not be distinguished on the basis of their performance on a battery of verbal and visual-spatial working-memory measures. Both subgroups evidenced a generalized deficit in working memory, which was interpreted as reflecting problems in the central executive system.

How should the lack of significant correlation between the SLI group's word recall on the CLPT and their performance on the language measures be interpreted? Results from this study, like those of other studies, suggest that working memory and language abilities are significantly correlated for children with intact language development. This same relationship was not observed for the children with SLI, though the modest positive association with MLU was similar to that for the controls. Given the observed link between working-memory span and normal language functioning, the lack of association for the SLI group might be viewed as an abnormal dissociation. Further, it might be argued that since word recall was not significantly correlated with language measures for the SLI group deficits in working-memory capacity are independent of the language difficulties of the children with SLI. Before making this assumption, limitations of the measures used to assess language functioning need to be considered. Like prior investigations, this study primarily relied on standardized measures of language abilities (along with a standard index of productive grammatical skills, MLU). Although these measures provide a reasonable assessment of selected areas of linguistic functioning, it is possible that other language measures would have yielded different results. Furthermore, more fine-grained analyses of psycholinguistic abilities within experimental tasks are needed to adequately test hypotheses regarding specific relationships between limitations in working-memory capacity and language skills.

In order to interpret the poor performance on working-memory measures by children with language disorder, it is necessary to consider the underlying assumptions about the direction of influence. There is a debate as to whether the association between larger memory spans and greater language skills is because better working memory supports acquisition and use of more advanced linguistic forms or if better language knowledge facilitates more efficient immediate recall, given the studies that have demonstrated the influence of
long-term lexical knowledge on immediate memory-span tasks (e.g., Engle, Nations, & Cantor, 1990; Gathercole, 1995; Goh & Pisoni, 1998). This is not just a methodological issue of devising an appropriate paradigm that solely taps working memory. Conventional distinctions between short- and long-term memory have become somewhat blurred in various recent conceptualizations of human memory, such as the construct of long-term working memory, proposed by Ericsson and Kintsch (1995), to account for text comprehension and other expert performance. For investigations of language impairment it is relevant to consider interactions (perhaps involving bidirectional influences) between restrictions in immediate memory span and reduced language knowledge in long-term store. It is important to clarify that our interpretation that children with SLI exhibit working memory deficits does not imply that only temporary or immediate memory processes are implicated, but that they are a contributing factor.

In conclusion, findings from this investigation indicate that children with SLI evidence greater deficits in verbal working memory capacity than normal language peers. The distinct pattern of word-recall error types, along with the different associations between working memory and language versus nonverbal cognitive skills that were observed for the two groups, hint at qualitatively different underlying processes. Additional research is needed to corroborate these findings, however, and to further investigate the issue of individual differences. Keeping in mind the heterogeneity of the SLI population, it is unlikely that any single factor will be found to account for the language difficulties of these children; there may be subtypes of SLI in which working memory limitations play a role and others in which they do not. Additional research is also needed (a) to compare the extent to which performance on measures of phonological working memory versus other measures of immediate memory span such as the CLPT predict language abilities of children with SLI and (b) to establish whether restriction in working-memory capacity for children with SLI is limited to verbal tasks or can be characterized as a generalized capacity deficit. Furthermore, future studies should attempt to clarify whether reduced working-memory capacity actually plays a causal role in developmental language disorders or reflects an independent area of difficulty for children with language and learning problems.

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References


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Appendix. Examples of sentence stimuli taken from the Competing Language Processing Task (Gaulin & Campbell, 1994).

<table>
<thead>
<tr>
<th>True/False</th>
<th>Word Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEVEL 1 (Group 1)</td>
<td>Trees have leaves.</td>
</tr>
<tr>
<td>LEVEL 2 (Group 1)</td>
<td>Apples are square.</td>
</tr>
<tr>
<td>LEVEL 3 (Group 1)</td>
<td>Carrots can dance.</td>
</tr>
<tr>
<td>LEVEL 4 (Group 1)</td>
<td>Rabbits read books.</td>
</tr>
<tr>
<td>LEVEL 5 (Group 1)</td>
<td>Houses can jump.</td>
</tr>
<tr>
<td>LEVEL 6 (Group 1)</td>
<td>Pencils eat candy.</td>
</tr>
<tr>
<td>LEVEL 7 (Group 1)</td>
<td>Airplanes can fly.</td>
</tr>
<tr>
<td>LEVEL 8 (Group 1)</td>
<td>Balls are round.</td>
</tr>
</tbody>
</table>