The Interaction of Syntactic Competence and Vocabulary During Reading by Deaf Students

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This research studied whether deaf students' component reading processes may interact with each other in a competitive manner. Vocabulary and syntax, two processes known to directly and adversely affect the comprehension of many deaf readers, were studied to determine if they may influence each other, affecting the contribution that each one makes separately to reading comprehension. Multiple regression analyses were conducted on predictor variables that included measures of vocabulary and syntactic competence, as well as a variable summarizing the interaction of vocabulary and syntax. The criterion variable was a composite of comprehension performance on a cloze procedure and on a more traditional reading test. Results were cross-validated by separate regressions on data samples from three populations of profoundly deaf readers: 100 adolescents from oral school programs, 113 adolescents from total communication programs, and 211 students entering a postsecondary institution that used total communication. In each regression, the Vocabulary X Syntax interaction variable emerged as the most critical of the three predictors. Further analyses of the interaction revealed that among subjects in the highest quartile of syntactic competence, the correlation between vocabulary competence and reading was significantly greater than it was in the lower three syntax quartiles. In contrast, the relationship between syntax and comprehension remained stable across all four quartiles of vocabulary competence. This suggests that unless deaf readers have achieved a reasonable level of syntactic competence it may be difficult for them to capitalize fully on their vocabulary knowledge. The finding that limitations in one reading process can interfere with the application of another is consistent with the theory of Capacity Constrained Comprehension of M. Just and P. Carpenter (1992). Because syntax can exert both a direct and an indirect influence on comprehension, it should be an important focus in instructional programs.

Background

Cognitive Theory and Reading

Carpenter and Just (1981), Rumelhart (1977), and Stanovich (1980) have advanced cognitive theories indicating that readers can be guided by multiple cueing systems. Comprehension, in their view, is less a result of a single, unitary reading process than it is the outcome of an array of reading processes. Readers construct mental productions of text that can be shaped by their knowledge of the following: (1) predictable combinations of letters, (2) letter-sound correspondences, (3) the inter-word relations specified by sentence syntax, (4) the word meanings in a reader's vocabulary, (5) sentence semantics, (6) the discourse structure of stories or expository materials, (7) knowledge recently acquired from reading earlier parts of a text, and (8) domain or world knowledge acquired through prior reading or experience. These combined processes are what largely constitute the cognitive environment in which each of the processes operates individually, and,
as will be discussed, this theory invites a suspicion that when competence in any key process is deficient, the contribution of other processes to reading comprehension may be adversely affected.

The term *interactive* is frequently used to characterize the interplay of component reading processes in a reader’s mind, and processes can interact with each other in a variety of ways. For one thing, they can pass along partial meanings to one another; the output of one process is acted on by one or more of the other processes. Processes can also interact by compensating for one another, according to Stanovich (1980). This occurs when a reader’s deficient competence relative to one process is offset by greater reliance on one or more other processes in which competence is relatively well developed. In some instances, this may be essentially a “do the best that you can with what you have” strategy. Stanovich and West (1983) have shown, for example, that low-ability readers with weak lexical retrieval processes tend to resort to heavy reliance on sentence context to facilitate retrieval of word meanings.

The activation and management of reading processes takes place in a reader’s working memory, and this alerts us to another possible kind of interaction, namely, that processes may compete with each other for working memory capacity. Newell and Simon (1972) coined the term *working memory* to distinguish this theoretical construct from its predecessor, *short-term memory*. Whereas short-term memory was exclusively viewed as serving a temporary storage function, working memory is thought of as the site of a processing function, as well. It is here that we temporarily store encoded words while we act on them to construct their combined meaning. Working memory has limited capacity, theoretically able to accommodate only seven plus-or-minus two bits of unrelated data, according to Miller (1956). The contents of working memory are also impermanent, and if they are neglected for even a short period, they tend to be forgotten, requiring their effortful reprocessing or retrieval from long-term memory.

According to Shankweiler and Crain (1986), effective readers increase the durability of working memory contents by recoding the visual image of printed words into their phonological equivalent. Research by Conrad (1979); Hanson (1990); Hanson and Fowler (1987); Hanson, Goodell, and Perfetti (1991); Hanson and Lichtenstein (1990); and Lichtenstein (1983) indicates that this same phonological recoding strategy may be contributing to the superior performance of relatively competent deaf readers.

Because of the finite limits of working memory, there exists a trade-off between its storage and processing functions: increased processing demands circumscribe temporary storage capacity, and elevations in storage obligations may reduce the processing function. Thus, when application of one reading process is relatively time-consuming, occupying working memory for a relatively extended duration of time, other potentially informative processes are obstructed because there is insufficient capacity to accommodate them.

The adverse effects of inefficient processing during reading have been thoroughly researched by Perfetti (1985) and particularly by Just, Carpenter, and others (see Carpenter and Just, 1989; Just and Carpenter, 1992; King and Just, 1991; and MacDonald, Just, and Carpenter, 1992) in the refinement of their theory of “capacity constrained comprehension.” Empirical findings from these studies included the following:

- Slow lexical retrieval encroaches on working memory capacity.
- Readers whose working memory capacity is limited by inefficient processing tend to experience difficulty making simultaneous use of important syntactic and semantic information available in a single sentence.
- Inefficient readers have difficulty processing sentences with complex syntax.
- Syntactic processing does consume working memory capacity to some extent, regardless of the efficiency of the reader.

These combined results indicate that the monopoly of working memory by a certain key, but inefficient, process necessarily obstructs the application of other, potentially informative processes. Perhaps most importantly, the work of Just, Carpenter, and others revealed that the reading comprehension of inefficient readers, those whose working memory capacity is reduced by one or more inefficient reading processes, is substantially inferior to the comprehension of readers with larger capacities.

According to the preceding theory and research,
interactions among reading processes are most likely to become evident when one or more of those processes are relatively deficient. The Just and Carpenter research suggests that when processes are deficient, they will adversely affect other processes in any number of ways. The compensatory theory of Stanovich (1980) holds that if one process is deficient, a reader may automatically turn to heavier reliance on some other process in order to offset that weakness and comprehend a text, a relatively inefficient desperation strategy resorted to by readers with lower ability.

Vocabulary, Syntax, and Deaf Readers

If deficiencies in a single critical reading process imply the potential for competitive interactions with other cueing systems, then the vocabulary and syntactic processes of certain deaf readers would seem likely candidates for affecting one another during reading. There is abundant research associating the comprehension problems of deaf readers with these two separate processes. Not one, but both, processes are potentially inaccurate and inefficient. Both vocabulary and syntax were among a set of 31 independent variables studied by Moores et al. (1987), and both of them emerged as members of a relatively small set of predictors of reading performance in two separate analyses, one focusing on deaf adolescents with deaf parents and a second, on deaf adolescents with hearing parents. Thus, it appears that both variables are highly implicated in the reading ability of deaf students. Recall also that vocabulary and syntax were implicated in the interactions found in much of the research by Stanovich and West (1983) and by Carpenter, Just, and others. It is certainly possible that other processes such as phonological recoding, knowledge of English prosody, or orthographic processing could be the source of an interaction among the component processes of deaf readers. However, for the reasons indicated, syntax and vocabulary seemed like a reasonable focus for examining whether the comprehension of deaf readers may be affected by the interaction phenomenon.

The direct influence of limited syntactic competence on the low reading comprehension of many deaf readers has been revealed by the research of Berent (1988); Geers and Moog (1987); Israelite (1981); Kelly (1993); Moores et al. (1987); Power and Quigley (1973); Quigley and King (1980); Quigley, Wilbur, Power, Montanelli, and Steinkamp (1976); Robbins and Hatcher (1981); Schmitt (1968); Scholes, Cohen, and Brumfield (1978); and Wilbur (1977). These studies suggest that many deaf readers may not notice English grammatical conventions that dictate the structure governing a particular sentence. Thus, it may be difficult for them to complete the mental operations that Carpenter and Just (1989) described as "coalescing" individual words into higher-order grammatical structures that signal the meaningful relations among the words. They may not easily see the word groupings appropriate for making sense of certain kinds of sentences. More than signaling meaningful relationships, syntactic coalescing during reading also combines individual words into a manageable number of chunks, which are more easily maintained in working memory. Without this chunking skill, many deaf readers may face an increased storage burden, accompanied by a higher risk that words will decay prematurely from working memory.

Past research has also implicated deficient vocabulary processes as an explanation for inferior performance by deaf readers, and this literature includes work by Geers and Moog (1987), LaSasso and Davey (1987), Moores et al. (1987), and Strassman, Kretschmer, and Bilsky (1987). According to Strassman et al., deaf readers tend to retrieve excessively specific word meanings where more general meanings apply. Adding to these results, King and Quigley (1985) reviewed the literature that shows the difficulties of deaf readers in comprehending figurative language. Davey and King (1990) accordingly argued the need for research on how deaf readers might better learn words from context to bolster small reading vocabularies. The combined vocabulary research thus suggests that many deaf readers either retrieve word meanings at great costs in time and attention, temporarily derailing higher-level comprehension processes, or retrieve inaccurate or imprecise word meanings, also resulting in limited comprehension. These conclusions raise the prospect of an interaction between vocabulary and other reading processes.

The research with deaf readers does include a number of studies that examined the separate interac-
tion of either syntax or vocabulary with some other component reading process. These studies revealed interactions that seemed compensatory in nature, where strength in one process ostensibly offset weaknesses in another. In a study of lexical processing, Fischler (1985) found that the semantic context of a sentence facilitated retrieval of word meanings to a larger degree among deaf college students than among same-age hearing readers. McGill-Franzen and Gormley (1980) demonstrated that subjects correctly processed truncated passive sentences more often when the sentences appeared in texts about well-known topics. There was some evidence that world knowledge compensated for inefficient syntax. Nolen and Wilbur (1985) examined the interaction between syntactic competence and the knowledge derived from reading complete paragraphs. Subjects were better able to comprehend relative clause sentences when they were imbedded in complete paragraphs than when they appeared as isolated sentences. On the surface, the results of the latter two studies suggest that well-developed syntactic knowledge may be somewhat dispensable for deaf readers. Ewoldt (1981) went so far as to speculate that at times the “print-to-meaning leap of deaf readers is unmediated by syntax” (pp.75-76).

The findings of the Fischler study are consistent with those of Stanovich and West (1983), namely, that less able readers rely more heavily on sentence context. Stanovich and West also determined, however, that such a use of context is an attention-dependent process, which has the likely effect of diminishing processing capacity that normally serves higher-level comprehension. One wonders whether resorting to conceptual level processes to aid syntactic analysis, as in the McGill-Franzen and Gormley study and the Nolen and Wilbur study, tended to encroach on working memory at the expense of higher-level comprehension. One wonders whether resorting to conceptual level processes to aid syntactic analysis, as in the McGill-Franzen and Gormley study and the Nolen and Wilbur study, tended to encroach on working memory at the expense of higher-level comprehension. While use of context may facilitate the accurate analysis of difficult syntax, the strategy may be inefficient, accompanied by drains on working memory capacity, and text-level comprehension may be jeopardized as a result. However, these studies with deaf readers did not directly examine the efficiency of utilizing reading processes in a compensatory manner.

Kelly (1995) did collect data on reading efficiency as part of an investigation that studied differences between secondary-aged skilled and average deaf readers; expressed in grade equivalents, the reading ability difference between the two groups was approximately nine grade levels. That research used the Moving Window paradigm developed by Just, Carpenter, and Woolley (1982) to record individual reading times for words that appeared in paragraphs about either familiar or unfamiliar topics. The findings revealed that the reading of both the average and skilled deaf readers was facilitated by familiar topics and by information appearing early in the experimental texts. However, this research also demonstrated huge differences in reading efficiency between the skilled and average readers. Word reading times of the average readers were almost twice as long as those of the skilled readers. In addition, the reading rhythms of skilled and average readers were significantly different; the average readers were twice as halting, as revealed by a dramatically larger variation of the word reading times calculated for each subject.

Recent analysis of data from Kelly’s (1995) study indicates that the difference in overall processing speed is attributable in part to differences in automaticity of word encoding, as determined by the relationship between word length and word reading time. Each additional letter in a word predicted an increase of 62 milliseconds in the word reading times of average deaf readers, while it added a minuscule 7 milliseconds to the times of skilled deaf readers. This research did not, however, isolate the efficiency of either vocabulary or syntactic processing. Merrills, Underwood, and Wood (1994) did find relatively slow and inaccurate word recognition performance among deaf readers.

The combined research on the syntactic, vocabulary, and reading comprehension performance of deaf readers can be recapitulated as follows: Inaccurate syntactic knowledge and vocabulary knowledge have been documented as exerting a direct and adverse effect on the comprehension of many deaf readers. Because these two processes are not applied skillfully by many deaf readers, it is possible that both of them may consume working memory capacity during reading. They also may pass on somewhat flawed information to be acted on by other reading processes. It is true that there is evidence that deaf readers compensate for limitations in syntax and vocabulary by relying more heavily on conceptual reading processes, such as application of world knowledge. However, there is also reason to sus-
pect that this reliance itself creates a drain on working memory capacity, one that is not encountered by readers who process vocabulary and syntax with relative automaticity. Finally, there is research indicating that average deaf readers are inefficient in basic reading processes such as word encoding and word recognition. This means that the working memory capacities of these readers face constant encroachment by basic encoding processes, decreasing the capacity for application of other processes like vocabulary and syntax. All told, the prior research and theory suggest the presence of a cognitive environment where it is highly likely that two reading processes as critical as vocabulary and syntax will affect one another.

Inefficient or inaccurate processing may not be the only adverse influence on the working memory capacity of deaf readers. Conrad (1979); Hanson (1990); Hanson and Fowler (1987); Hanson, Goodell, and Perfetti (1991); Hanson and Lichtenstein (1990); and Lichtenstein (1983) have produced some evidence that relatively skilled deaf readers may use a phonological strategy for temporary storage of words in working memory. As mentioned earlier, Shankweiler and Crain (1986) have indicated that this is a relatively routine phenomenon among hearing readers.

Hanson and Fowler (1987) reasoned that some deaf readers may acquire this sound-based strategy through lipreading experiences or speech training, and these tend to be those who are relatively skilled. They may be able to sustain in working memory a more enduring record of English surface structure, including grammatical conventions, leading to more precise comprehension of meaning. However, the majority of deaf readers, who have a limited command of English phonology, may face a functionally reduced working memory capacity, regardless of their processing burden or their processing efficiency, because they do not skillfully apply phonological recoding strategies. Lillo-Martin, Hanson, and Smith (1992) found evidence that problems with relative clause sentences may stem more from basic difficulties with phonological processing than from deficient syntactic knowledge.

Purpose of the Research

Rather than determining factors that influence the acquisition of competence in certain reading processes, the present study examined how critical reading processes may influence each other. If a single inefficient process increases the chances of an interaction among reading processes, particularly one that is competitive, then many deaf readers may face a twofold threat because of their prevalent difficulties with both vocabulary and syntactic processes. This risk is compounded by evidence suggesting that the working memories of many deaf readers may be excessively occupied by laborious encoding of incoming words. Finally, earlier research also shows that the processing capacity of many deaf readers may be functionally diminished by underdeveloped phonological recoding strategies. As a result of these combined factors, deaf readers may be precisely the population most in need of fluent reading processes and most obstructed when even one of those processes is not efficient.

It therefore was reasonable to test whether the vocabulary and syntactic processes of deaf readers interact with each other in a competitive manner. This study addressed these questions: Do deaf readers who have not yet achieved a relatively high level of syntactic competence show less ability to apply their vocabulary knowledge than those who have achieved higher syntactic ability? Also, are deaf readers who demonstrate relatively low vocabulary ability less able to apply syntactic competence than those with higher vocabulary ability?

Delimitations

Recent research has identified important gender effects in language processing, for example, the work of Shaywitz et al. (1995). However, this study, like the work of Carpenter, Just, and colleagues, Geers and Moog (1987), Moores et al. (1987), and Stanovich and West (1983), does not examine gender as a variable that may affect the nature of an interaction between component reading processes.

Method

Subjects

Samples from three populations of deaf readers provided the data for this research: adolescents trained in oral school programs, adolescents trained in total com-
munication programs, and students entering a postsec-
ondary institution using total communication.

Adolescents. Data from all adolescent subjects came
from a study funded by the National Institutes of
Health (NIH) of factors predicting literacy in deaf ado-
lescents by Geers and Moog (1987) and Moores et al.
(1987). That research examined the relationships be-
tween literacy ability and a multitude of demographic,
educational, communication, and component process
variables, including vocabulary and syntactic knowl-
dege, but it did not explicitly examine the interaction
between vocabulary and syntax as a predictor of read-
ing comprehension. Subject selection criteria for the
study were as follows: age within 2 months of 16 or 17
years, better ear average hearing loss in the speech
ranges greater than 85 dB, onset of hearing loss by age
2, a nonverbal IQ no more than 1 standard deviation
below normal, and no additional handicaps.

One hundred of the subjects recruited according to
these criteria also had been enrolled exclusively in
school programs that used oral communication during
the preschool and elementary years. These students
were recruited and tested by the strand of the study
conducted by Geers and Moog (1987). Forty-nine per-
cent were male and 51% were female.

The strand conducted by Moores et al. (1987) fo-
cused on students who had been enrolled in total com-
munication (signing and speech combined) educational
programs since the age of 4 years or younger, while
meeting the other basic selection criteria. Half of these
students had hearing parents, and half had deaf par-
ents. Complete data sets for the variables of interest
brought this number to 56 subjects of hearing parents
and 57 subjects of deaf parents. Data from these two
total communication groups had been analyzed sepa-
rately in the original NIH study, and in both analyses,
vocabulary and syntactic performance emerged as two
of a small set of the most significant predictors of read-
ing performance. In addition, t-tests of differences be-
tween group means on the two criterion measures of
reading comprehension to be discussed below indicated absence of a significant difference (.05 level)
on both measures. Thus, in this study, in order to con-
stitute a larger sample on which to conduct the
analyses, the two groups were combined into a single
data set of 113 students from total communication pro-
grams. Fifty-two percent were male and 48% were
female.

Entering postsecondary. The 211 postsecondary subjects
had all been admitted for study at Gallaudet University
for the fall term in 1992. Some portion of these would
be entering freshman-level courses for credit, while the
remainder would be entering noncredit developmental
English and mathematics programs until their compet-
ence indicated readiness for freshman-level courses.
Those included in this research met the key criteria
specified for the adolescent subjects: better ear average
hearing loss 85 dB or greater (median 102), age at onset
of deafness 2 years or younger, and no additional hand-
icaps. Among the students meeting these criteria, 41
had deaf parents. The median age for the 211 postsec-
ondary subjects was 20 years. Fifty-seven percent were
male and 43% were female.

Measures of Reading Comprehension
and Component Processes

Adolescent syntactic knowledge. The Test of Syntactic
Abilities (TSA), developed by Quigley, Steinkamp,
Power, and Jones (1978), was used to measure the
English syntactic ability of the adolescent subjects. The
TSA battery includes a screening test consisting of 120
items, which tests knowledge of nine of the major syn-
tactic structures in English. This is a paper-and-pencil
test, in multiple-choice format, which requires testees
either to detect errors in English phrasing or to identify
the meaning expressed by one of the major structures.
The original norming study of the TSA indicated a
Kuder-Richardson formula 20 (K-R 20) reliability of
.98. In this study, performance is summarized as the
percentage of the items answered correctly.

Adolescent vocabulary knowledge. Reading vocabulary
was measured by the Reading Vocabulary subtest of
the California Achievement Test (CTB/McGraw-Hill,
1977). This multiple-choice paper-and-pencil test in-
cludes 30 items that focus on words with similar and
opposite meanings as well as words with multiple
meanings. Raw scores were converted to grade equiva-
lent scores that can range from 2.0 to 12.9.
Adolescent reading comprehension. One of the measures used to assess reading comprehension of text was the Reading Comprehension subtest of the seventh edition of the Stanford Achievement Test—Hearing Impaired Edition (SAT–HI) developed by Madden, Gardner, Rudman, Karlsen, and Merwin (1982). This is the most widely used test for measuring the reading ability of hearing-impaired youth, and norms are available for hearing-impaired and hearing youth. The test format is a series of passages each followed by between five and eight multiple-choice questions. The number correct, a maximum of 60, is converted to a scaled score, ranging from 316 to 827. The study that produced norms for hearing impaired readers by Allen (1986) indicated a K-R 20 reliability ranging between .89 and .91 for the forms of the test used most frequently with deaf adolescents.

While the SAT–HI measured comprehension through questions answered at the conclusion of reading, a cloze exercise was used to measure comprehension processes while the readers were engaged in the act of constructing meaning. A story entitled “Devil’s Trick,” judged to be at the 10th-grade level of difficulty, was converted to a cloze passage. The first three paragraphs of the 700-word text were left intact, and then every fifth word was deleted according to the usual cloze procedure and replaced with a blank space. Fifty words were deleted in this way, thus creating a 50-item instrument. The readers’ task was to fill each blank with a word that was judged both semantically consistent with the meaning of the story and syntactically consistent with the sentence in which the blank appeared. Performance was summarized as the percentage of responses that met both of these two criteria, which naturally included insertions that were verbatim to the original words of the story.

In order to generate a more stable estimate of reading comprehension, combining comprehension performance both during and following reading, the two measures of reading comprehension were collapsed through factor analysis into a single factor score.

Postsecondary syntactic knowledge. The English Structure component of the Gallaudet University English Placement Test was used to measure the knowledge of English conventions among the postsecondary subjects. The English Placement Test, developed by the English Department of Gallaudet, is administered for placement purposes to all students admitted to the university. The English Structure component consists of 150 multiple-choice items that present one of three types of tasks: selection of a single grammatical sentence from among four alternatives, completion of a sentence by choosing the single grammatical complement from among alternatives, or selection of a grammatically phrased question that would be answered by an identified phrase. The responses of the study sample produced a K-R 20 reliability of .96. Performance was summarized as the percentage correct.

Postsecondary vocabulary knowledge. The Vocabulary component of the Gallaudet University English Placement Test was used to measure the vocabulary knowledge of the postsecondary students in the study. This is a 100-item multiple choice test designed to measure understanding of common, everyday words and idioms. The K-R 20 reliability calculated from this sample was .95. Performance was summarized as the percentage correct.

Postsecondary reading comprehension. One of the tests used to measure reading comprehension of postsecondary subjects was the Degrees of Reading Power (College Board, 1986). This test parallels the “Devil’s Trick” passage used with the adolescent subjects, because it also is a cloze test. It is 70 items long, consisting of deletions of critical content words made in 10 expository passages that increase in difficulty over the course of the test. Subjects respond by choosing among five answer alternatives, all of which complete a grammatical sentence but only one of which fits with the meaning of the full passage. Depending on the results of an initial screening test, subjects were administered one of two forms of the test. Analysis of subject responses indicated that the more difficult E3 form of the test had a K-R 20 reliability of .91, while the E5 form produced a K-R 20 coefficient of .87. Raw scores from the two forms were converted to the common DRP scale, which ranges from 0 to 99.

The second comprehension measure was the Reading component of the Gallaudet University English Placement Test. This component consists principally
of a series of passages drawn from magazines, newspapers, and textbooks, and these, like those of the SAT-HI, are each followed by multiple-choice questions. On this test, the items are designed to measure ability to make inferences, follow directions, determine sequence of events, and identify main ideas. There are a total of 75 items. Analysis of the responses of this sample indicated a K-R 20 reliability of .91. Performance was summarized as the percentage correct.

As with the adolescents, the two measures of post-secondary reading comprehension were consolidated into a single score through factor analysis.

Analysis

A cognitive interaction of component reading processes can be revealed by testing the significance of the statistical interaction of the measures of those reading processes. If a cognitive interaction between vocabulary and syntax is present, the variable representing the statistical interaction of the two processes should be a significant variable in a regression equation predicting reading comprehension. The rationale for this is as follows: A cognitive interaction of two component processes is present if the contribution of one of the variables to reading comprehension is related to level of ability on the second variable. This is analogous to a significant interaction in a two-factor analysis of variance (ANOVA), where the effect of Factor A on the dependent variable is not uniform in all levels of Factor B; that is, within some level of Factor B, Factor A is relatively potent compared to its effect at other levels of Factor B. When the analysis procedure is regression instead of ANOVA, as dictated by the continuous nature of the independent variables, the significance of the interaction is tested by obtaining the product of the separate independent variables and including that value in each subject’s data as a possible term in the regression equation.

Stepwise multiple regression reveals the relative statistical importance of predictor variables by forcing them to compete for membership in a final regression equation. In this study, variables that did not add significantly to predicted variance (at the .05 level) were not admitted into the equation by the stepwise procedure. A second criterion of a variable’s significance is a t-test of the difference from zero of the variable’s standardized coefficient in the full prediction model. In order to determine variable significance in these ways, both a stepwise and a forced entry regression procedure were conducted on each of the three data sets.

Design

Knight (1984) pointed out that interpretations of regression results are complicated by the presence of strong relationships between any two independent variables. When two independent variables are highly correlated, it is difficult to distinguish their relative impact on the dependent variable on the basis of a single analysis. Even though one of the two variables might demonstrate significantly greater predictive power than the other, there is a possibility that their positions could be reversed given the novel structure of a different data set comprising the same variables. In order to distinguish reliably among the effects of predictor variables that are highly correlated with each other, Knight recommended cross-validating results by determining whether a similar ordering of independent variables obtains from analyses of two or more samples of data. In light of possible correlations among predictor variables in this study, results were cross-validated with three separate analyses performed on the different data sets.

Limitations

As correlational research, this study does not purport to isolate causal relationships among variables. This research does not use experimental procedures, such as those of Just, Carpenter, and colleagues, which might reveal precisely why either the vocabulary or syntax of deaf readers may affect the other. Rather, this study addresses itself solely to whether results emerge that are consistent with a competitive interaction occurring between syntax and vocabulary processes.

Results

Descriptive Statistics

Table 1 displays descriptive statistics for each of the three groups’ two measures of reading comprehension and for their single measures of syntax and vocabulary.
Table 1  Mean, standard deviation, and possible range of predictor and criterion variables for each data set

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Possible Range</th>
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<tbody>
<tr>
<td><strong>Adolescents in oral programs (n = 100)</strong></td>
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<td></td>
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<tr>
<td>Reading Comprehension:</td>
<td>669</td>
<td>47</td>
<td>316–827</td>
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<td>Stanford Achievement Test (scaled score)</td>
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<td></td>
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<tr>
<td>Reading Comprehension:</td>
<td>50.3</td>
<td>20.9</td>
<td>0–100</td>
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<tr>
<td>cloze passage (% correct)</td>
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<td></td>
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<tr>
<td>Vocabulary: Vocabulary subtest, California</td>
<td>7.65</td>
<td>3.06</td>
<td>2.0–12.9</td>
</tr>
<tr>
<td>Achievement Test (grade equivalent)</td>
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</tr>
<tr>
<td>Syntax: Screening test of Test of Syntactic Abilities (% correct)</td>
<td>90.85</td>
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<td>0–100</td>
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<td><strong>Adolescents in total communication programs (n = 113)</strong></td>
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<td>56.2</td>
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<td>cloze passage (% correct)</td>
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<td>2.64</td>
<td>2.0–12.9</td>
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<td>Syntax: Screening test of Test of Syntactic Abilities (% correct)</td>
<td>79.8</td>
<td>16.8</td>
<td>0–100</td>
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<td><strong>Entering postsecondary students (n = 211)</strong></td>
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<td>15–99</td>
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<td>Ready Comprehension:</td>
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<td>Degrees of Reading Power (scaled score)</td>
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<td>Syntax: Structure subtest, Gallaudet English Placement Test (% correct)</td>
<td>71.9</td>
<td>14.5</td>
<td>0–100</td>
</tr>
</tbody>
</table>

Table 2 shows the extent to which the three predictor variables are interrelated within each of the three data sets. Inspection of the correlations and their probabilities reveals that all predictor variables in all three data sets are highly collinear. This justifies and even necessitates the cross-validation approach used here.

Regression Results

Table 3 displays the results of regression analyses that examined the prediction of the Reading Comprehension factor scores from the three independent variables, Vocabulary, Syntax, and the Syntax X Vocabulary interaction. Three sets of results appear, one for each data set. Table 3 shows the order that the variables entered the equation in a stepwise regression, standardized regression coefficients for the full models, and the probabilities of the t-values testing the coefficients' difference from zero.

The oral school programs regression revealed significant prediction of Reading Comprehension by the three independent variables, $R^2 = .77, F(3, 96) = 107.7, p < .001$. In the stepwise regression, the Syntax X Vocabulary interaction entered the equation first, indicating this variable shares the greatest amount of variation with Reading Comprehension. The Vocabulary predictor entered the equation second, contributing a far lesser but still statistically significant proportion of prediction of the dependent variable, incrementing the $R^2$ by .0788. The Syntax variable, when pitted against the other two predictors in the stepwise procedure, did not add sufficient prediction to meet entry requirements. In the full model, the Syntax X Vocabulary interaction produced the largest standardized coefficient matched by the lowest probability of the t-test of its difference from zero, significant at the .001 level. The Vocabulary coefficient was significant at the .05 level, while the Syntax coefficient did not approach significance. This leads to an initial conclusion that the Vocabulary X Syntax interaction makes an important contribution to reading comprehension.

The first cross-validation of these findings appears in the middle rows of Table 3, which show the regression results from the data of students enrolled in total communication school programs. In this analysis, the three predictor variables combined for a significant $R^2$ of .64, $F(3, 109) = 65.9, p < .001$. More germane to the question of interest, the Syntax X Vocabulary interaction once again was the first to enter the stepwise equation, and, again, its coefficient was the largest in the equation for the full model. Also, as in the first re-
Table 2  Bivariate correlations among predictor variables

<table>
<thead>
<tr>
<th></th>
<th>Oral programs</th>
<th>Total communication programs</th>
<th>Postsecondary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>S</td>
<td>V × S</td>
</tr>
<tr>
<td>Vocabulary (V)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Syntax (S)</td>
<td>.68*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>V × S</td>
<td>.99*</td>
<td>.74*</td>
<td>.98*</td>
</tr>
</tbody>
</table>

*p < .001

Table 3  Regression results: Vocabulary, Syntax, and Syntax × Vocabulary as predictors of Reading Comprehension factor scores in three data sets

<table>
<thead>
<tr>
<th>Oral programs (n = 100)</th>
<th>Order of entry in stepwise regressive</th>
<th>Beta in full model</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R² = .77; F(3, 96) = 107.7; p &lt; .001)</td>
<td>Vocabulary 2nd</td>
<td>−2.51</td>
<td>.0045</td>
</tr>
<tr>
<td></td>
<td>Syntax not entered</td>
<td>.05</td>
<td>.7182</td>
</tr>
<tr>
<td></td>
<td>Syntax × Vocabulary 1st</td>
<td>3.29</td>
<td>.0007</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total communication programs (n = 113)</th>
<th>Order of entry in stepwise regressive</th>
<th>Beta in full model</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R² = .64; F(3, 109) = 65.9; p &lt; .001)</td>
<td>Vocabulary 2nd</td>
<td>−.956</td>
<td>.0367</td>
</tr>
<tr>
<td></td>
<td>Syntax not entered</td>
<td>.12597</td>
<td>.3629</td>
</tr>
<tr>
<td></td>
<td>Syntax × Vocabulary 1st</td>
<td>1.598</td>
<td>.0031</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entering postsecondary (n = 211)</th>
<th>Order of entry in stepwise regressive</th>
<th>Beta in full model</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R² = .83; F(3, 207) = 344.0; p &lt; .001)</td>
<td>Vocabulary not entered</td>
<td>−.135</td>
<td>.3727</td>
</tr>
<tr>
<td></td>
<td>Syntax 2nd</td>
<td>−.496</td>
<td>.0001</td>
</tr>
<tr>
<td></td>
<td>Syntax × Vocabulary 1st</td>
<td>1.503</td>
<td>.0000</td>
</tr>
</tbody>
</table>

Regression, the main effect of Vocabulary was the second predictor to enter the equation, and the size of its coefficient in the full model was once more statistically significant. The Syntax variable did not meet entry requirements in the stepwise procedure, nor was the size of its coefficient statistically significant in the full model. The replication of the results from the first regression leads to a conclusion that the favorable standing of the Syntax × Vocabulary interaction revealed by the earlier analysis discloses a legitimate superiority of prediction rather than an artifact of the structure of the data set.

The second cross-validation is presented in the bottom rows of Table 3, which show the regression results for the postsecondary students. The regression resulted in statistically significant prediction, an $R^2$ of .83, $F(3, 207) = 344.0, p < .001$. As in the earlier two regressions, the interaction of Syntax and Vocabulary was the first predictor to enter in the stepwise procedure. In contrast to the earlier two regressions, Syntax was the second predictor to enter the equation. Of greatest importance, the recurring predominance of the Syntax × Vocabulary interaction distinguishes that variable as an influential predictor of reading comprehension ability.

Examining the Interaction

The three prior analyses revealed that the two component skills of Syntax and Vocabulary may influence the effect that the other exerts separately on Reading Comprehension performance. However, the results are still somewhat ambiguous. It could be that at certain levels of syntax knowledge the relationship of vocabulary to...
reading comprehension is relatively stronger than it is at other levels of syntactic ability. Alternatively, it could be that syntax becomes a particularly strong predictor of reading comprehension at specified levels of vocabulary performance. To determine the nature of the interaction, I examined the relationship of vocabulary to reading comprehension separately within each quartile of syntax scores, and I calculated the relationship between syntax and reading comprehension within the four quartiles of vocabulary scores.

Table 4 shows the results of this finer-grained analysis of the relationships between Reading Comprehension and the two predictor variables. The top half of the table shows data from the adolescent subjects divided into quartiles on each of the two predictor variables, as precisely as the distributions of data would allow. In order to base each correlation on a larger set of subjects, the data of the two adolescent groups were combined since they both exhibited the same pattern of results in the initial regression analyses, which were based on the same measures. The intraquartile correlations for the entering postsecondary students constitute the bottom half of the table.

Table 4 shows that the Reading Comprehension—Vocabulary correlations of the adolescent subjects were fairly uniform within the lower three syntax quartiles, ranging only between .27 and .36. Although these each were statistically significant at the .05 level, the fourth and highest quartile of syntax generated a dramatic elevation to a correlation of .70 between vocabulary and reading comprehension. This indicates a differentially strong relationship between reading comprehension and vocabulary in this highest quartile. Among the subjects in this high-syntax group, any relative advantage in vocabulary competence translates more clearly into superiority in reading comprehension performance.

Turning to the Reading Comprehension—Syntax correlations calculated within the quartiles of adolescent vocabulary scores, a different pattern appears. Although each of the quartiles generated high correlations between Reading Comprehension and Syntax, the coefficients were rather uniform across each set of data, varying only between .60 and .66 among the four quartiles. This uniformity indicates that syntax knowledge contributes to reading comprehension in a similar way regardless of the level of vocabulary knowledge; vocabulary ability seemed neither to foster nor hinder
the contribution of syntactic knowledge to reading comprehension.

The correlations of the entering postsecondary students show a similar result. The correlations between vocabulary and reading comprehension in the lowest three syntax quartiles were relatively strong, and these were similar in strength to the vocabulary-reading correlation in the highest syntax quartile of the younger adolescent readers. All were in the range of .65 to .73. In the highest quartile of postsecondary syntax, however, the correlation between vocabulary and reading comprehension increased substantially to .88.

In contrast, at the very bottom section of Table 4, the correlations between syntax and reading comprehension are reasonably uniform across the four quartiles of vocabulary scores, although not to the same extent as they were for the adolescent subjects. These results, like those derived from the data of the adolescents, suggest that these readers are better able to capitalize on their vocabulary knowledge once they have achieved a certain level of syntactic knowledge. As an alternate way of viewing these relationships, in the top quartiles of both the postsecondary and the adolescent groups, the slopes of the vocabulary-comprehension regression equations were double those in the equations of the lower three quartiles. That is to say that within the highest syntax quartiles of both groups, any elevation in vocabulary performance was accompanied by an increase in comprehension performance that was twice that associated with a similar elevation in vocabulary within the lower quartiles. Vocabulary knowledge thus seems much more retrievable and applicable to reading comprehension, if a reader achieves a relatively high level of syntactic competence. Variations in vocabulary knowledge, in contrast, do not seem to exert the same influence on the relationship between reading comprehension and syntax.

Discussion

Syntactic Competence Influencing Vocabulary Application

These results are consistent with a competitive interaction between two component reading processes. If a deaf reader's syntactic competence is limited, comprehension may be adversely affected for reasons extending beyond the direct influence documented by earlier research. That is, limited syntactic knowledge also may detract from comprehension indirectly by obstructing the reader's ability to apply stored vocabulary knowledge. Two possible explanations for this are that either the reader unknowingly misinterprets syntactic relations and this misleads vocabulary processing, or laborious syntactic analyses circumscribe capacity needed for lexical processing.

Those subjects in this study who had achieved relatively high levels of syntactic competence were better able to capitalize on vocabulary ability to foster reading comprehension. The statistical significance of the Syntax X Vocabulary interaction in the three regression equations was the first indication that either vocabulary competence or syntactic ability may have affected the relationship of the other to reading comprehension performance. Subsequent calculation of intraquartile correlations revealed that the relationship between vocabulary and reading comprehension is dependent on syntactic ability. In contrast, the syntax-comprehension correlations, though high, varied minimally as a function of vocabulary ability.

The finding here was not simply that readers with better syntactic ability also tended to have better vocabularies at their disposal, although this was generally true. Rather, within the highest syntax group, any relative advantage in a reader's vocabulary ability predicted a much larger increase in reading comprehension than a similar advantage predicted among subjects with lower syntactic ability. By the same token, any relative deficiency in a high-syntax subject's measured vocabulary translated into a larger decline in reading comprehension, compared to subjects with lower syntactic ability.

According to the theory of Just and Carpenter (1992), the interplay of reading processes can be likened to the daily rhythm of a kitchen in a five-star restaurant, with its finite number of chefs and cooking stations. If the culinary staff is highly skilled in the meal orders called for by diners during a certain 24-hour period, then processing will be swift and the capacity of the restaurant's kitchen is functionally enlarged on that day. On another day, a glut of epicures, who all order a certain elaborate, relatively unpracticed
delicacy, will occupy food preparation resources for long durations, reducing the number of diners who can be fed. The same reduction in functional capacity could occur if a less skilled chef substituted for one of the regular staff. When several cooks must collaborate on a single creation, there also will be times when an error at one stage of food preparation will either misguide or prolong another cook’s work at a later stage, jeopardizing the quality of the final dish.

Carpenter and Just (1989) observed, “Readers are seldom aware of syntactic difficulties during their processing of well-written text” (p.55). Extending this observation to the restaurant metaphor, it appears that smoothly functioning syntax might be analogous to a skillful waiter. Although never actually applying food to skillet, this professional’s skill and vigilance allow the meal to proceed without incident. However, when syntactic processes are inefficient or inaccurate, there is no longer a benign sentinel deftly taking orders, anticipating requests, and serving the prepared food. In both reading and waiting tables, ineptness or inattention often produces unsatisfactory results.

The theory and empirical research of Carpenter, Just, and colleagues suggests the ways that deficient syntactic competence can interfere with application of vocabulary competence. Conscious, effortful processing of syntax bleeds away resources that could normally be invested in accessing vocabulary knowledge. Effortful syntactic processing will also be slower, increasing the danger that the words of meaningful word groups will decay from working memory before a meaning is constructed that includes them all. If a reader has limitations in applying the coalescing function of syntax, then phrases of text often must be maintained as strings of discrete word-units, increasing the storage burden on working memory, leaving less capacity for other processes, and aggravating the potential for word decay. Related to this, inefficient syntax will suggest relations among words whose meaning is either vague or inaccurate. All of the latter factors lead to the generation of degraded information to be acted on by other reading processes. In order to determine exactly which of these alternatives tends to influence the comprehension of deaf readers, it would be necessary to employ experimental tactics parallel to those used by Carpenter, Just, and colleagues. However, the results of this study do serve to reveal that one or more of these syntax-related factors seem to constrain the manner in which vocabulary knowledge contributes to the comprehension of deaf readers. Thus, even though a certain number of studies show instances of deaf readers making compensatory use of alternative reading processes to offset syntactic difficulties, the present findings indicate that development of syntactic competence ought to be accorded a high priority in reading programs for deaf children and youth.

Instructional Implications

I list three broad instructional guidelines derived from the results of this study, followed by thoughts on developing syntax competence, which appears to be a process worthy of considerable instructional attention, given its direct and indirect relationship to reading comprehension. First, whatever instructional method is used, it should promote performance that is not only accurate but also relatively attention free. If the reader must apply a process slowly and intentionally there is a high likelihood that other processes will be adversely affected. Second, instructional programs need to exert simultaneous efforts to improve competence in an array of cueing systems. This research revealed just one interaction between two reading processes that have been notorious for limiting the comprehension of deaf readers. There are other processes, however, that are also at high risk of adversely affecting reading comprehension, both directly and indirectly (by circumscribing the contributions of neighboring processes that also warrant instructional attention, including automatic word encoding and, perhaps, phonological recoding to support working memory duration). Third, instruction should be authentic in the sense that it shepherds students to the point of being able to apply a process in the realistic context of whole text. To confine instruction to isolated drills exclusively would be to ignore the special advantages as well as the frequent burdens of applying a certain target process in a cognitive environment where other component processes must also be managed.

Turning to the issue of developing syntactic competence, it appears that those working in deaf education do not yet know the best way to teach syntax to
their students. However, considerable theory and research on language learning (see Carroll, 1986, and Krashen, 1977) indicates that learners have a greater likelihood of developing competence in a specific linguistic convention if they are afforded frequent opportunities to notice that convention in the context of meaningful communication. This kind of experience also leads to applying a process in a manner that is relatively attention free. Krashen refers to such fluent use of a language convention as “acquired” competence.

Neuman and Koskinen (1992) have argued that videotaped material can provide a source of context for reading the print that appears as captions to the video action, which they referred to as “comprehensible input” (p. 95). They produced evidence that this context fostered vocabulary acquisition of hearing children learning English as a second language. The action of the video provided a rich context of meaning, and, importantly, this meaning was readily accessible to the viewers. The same context would have been far less accessible if the low-ability readers were required to construct it solely through their reading of extended text rather than through observing the video action.

Traditionally, the primary goal of captioning for deaf people has been to facilitate access to the information that is spoken on video programming. However, given the chronic problems with syntax, it seems desirable to use captioning more aggressively and strategically, exploiting the video action to promote acquisition of target forms of printed English. One such project, which uses video action to render chronically difficult English syntactic structures more contextualized and thus more understandable, was initiated by Kelly (1994).

But what are teachers of deaf children to use, given the kinds of materials generally available in the classroom? Quigley and King (1982) produced a special basal reading series in which the sentences in many of the readers were marked to highlight the grammatical relations among words. However, even though LaSasso (1987) found that these materials had received widespread use in educational programs for deaf readers, the syntactic problems documented long ago by Quigley et al. (1976) still persist.

More recently, many programs for deaf readers have adopted the Whole Language (Goodman, 1968) philosophy of teaching reading. A compilation by Abrams (1991) shows numerous applications of Whole Language methods in instructional programs for deaf children. This approach recommends use of whole texts (vs. text segments) and emphasizes the teaching of component processes only as needed and then only in a meaningful context.

This makes excellent sense as an approach with deaf readers. Teachers can encourage use of sentence and passage contexts in a compensatory manner, temporarily offsetting the problems associated with laborious encoding and lexical access, and as a result, generating more stimulating experiences to improve those basic processes. In addition, by encouraging use of original instead of simplified texts, Whole Language, according to Ewoldt (1983), “gives students the opportunities to experiment with new [syntactic] structures” (p. 5).

Dolman (1992) has argued that deaf children, like disadvantaged hearing children, may need more direct instruction in certain reading processes. Whole Language is not necessarily opposed to the direct teaching of component processes, even out of context. Reading Recovery (Clay, 1985) is one instructional program that espouses Whole Language principles, yet encourages selective use of direct instruction to eliminate incorrect reading strategies at an early age.

Another instructional approach, which is consistent with Whole Language and which holds promise for improving syntactic competence, is Repeated Reading (see Dowhower [1987] for a review of the Repeated Reading literature). This method recommends repetitive reading of a single practice text until a student achieves some predetermined level of accuracy or fluency. The rationale is that through frequent exposure to the same text, students will develop sufficient automaticity in word encoding and lexical retrieval to better detect the grammatical relations among words. This rationale is very compatible with the results of this study: namely, when a certain component process becomes more automatic or fluent, a reader can devote more attention to gaining control of a second process. Applying this rationale to syntax, during Repeated Reading the student reader will discover the phrasing that is necessary in order to make sense of sentences. The research literature documents many successful ap-
Applications of Repeated Reading with hearing children. However, not a single application with deaf children has been reported. Repeated Reading thus seems to be a method that justifies examination through future research.

References


