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ABSTRACT

Forty-three high school students (14 poor, 13 average, and 16 good readers) were given three different measures of memory capacity to determine if they differed in working memory, traditional memory span, and chunking capacity. Several experimental tasks followed to determine if differences in the memory factors were related to specific components of reading. These tasks included lexical decision, letter matching, reading rate, synonym match, speeded comprehension, and word recoding. Comprehension, IQ, spelling, mathematics word problems, and vocabulary scores were collected from school records. The three memory tasks, lexical decision, and synonym match discriminated significantly among the groups, with general ability controlled. Regression analyses suggested each memory variable was explained by a different constellation of the other reading factors. Findings suggest that the relationship between working memory and reading comprehension is not isolable from the type and amount of information encoded during its measurement. (One table of data is included.) (Author/RS)

Working Memory and Reading Skill in High School Students

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Running Head: WORKING MEMORY AND READING SKILL

Abstract

Forty-three poor (N=14), average (N=13), and good (N=16) high school readers, were given three different measures of memory capacity to determine if they differed in working memory, traditional memory span, and chunking capacity. Several experimental tasks followed to determine if differences in the memory factors were related to specific components of reading. These tasks included lexical decision, letter matching, reading rate, synonym match, speeded comprehension, and word recoding. Comprehension, IQ, spelling, mathematics word problems, and vocabulary scores were collected from school records. The three memory tasks, lexical decision, and synonym match discriminated significantly among the groups, with general ability controlled. Regression analyses suggested each memory variable was explained by a different constellation of the other reading factors. Results were interpreted as indicating the relationship between working memory and reading comprehension was not isolable from the type and amount of information encoded during its measurement.

Memory and Reading Skill in High School Students

Daneman and Carpenter (1980) appear to have introduced the first measure of immediate memory that is substantially correlated with complex measures of reading in mature readers. They documented that, historically, simple measures of memory span such as digit and word span tasks were not reliably correlated with complex measures of reading performance such as reading comprehension. They suggested that this was the case because the simple span measures tapped only a very limited aspect of immediate memory storage. The task they then introduced required the reader to read or process an increasingly larger set of short sentences while also remembering the last word from each one. The complex reading span task, as this test is known, consistently produces high to moderately high correlations with measures of reading comprehension (Daneman & Carpenter, 1980; Lee-Sammons, & Whitney, 1991).

Findings with the reading span test to date are consistent with the idea that the complex span represents activation capacity: the total amount of information that the reader can hold open in memory while text processing at the sentence level is proceeding. The simpler word span test, on the other hand, is more akin to the historical notion of STM. However, this test does seem to correlate with reading under the constraint that the task tap into the reader's capacity for articulatory coding (Lee-Sammons & Whitney, 1991). Apparently, this is the phrase chunking that good readers normally do as they convert the serial procession of written words in a sentence into an acoustic abstract form that encodes its intonation contour. Baddeley (1986) gave this aspect of immediate verbal memory the term, the articulatory loop. Other researchers have noted that the size of these chunks correlates highly with complex measures of reading (e.g., Rothkopf, 1980).

So, at least two measures of immediate memory capacity seem to hold considerable promise in research and, perhaps application, in reading. In this study we attempted to translate these two types of measures into a format that might be given in the school environment. We also wished to know whether good and poor readers differed in their working memory and chunking capacities. Finally, we wanted to know whether the two measures assessed different aspects of immediate memory. These questions were embedded in a context of data collection which included lower order measures of reading. Consequently, the issue of whether lower order reading skills mediated the effects of memory capacity on comprehension could also be examined.

Method

Subjects

The study included 43 high school students in grades 9 through 12, drawn from six small intact classes in a special, make-up academic program in a rural school system. The study group included 19 girls and 24 boys. The comprehension subtest of the California Achievement Test was used to sort students into the three groups, using as a criterion the 30th percentile for the poor readers (N=14) and the 60th percentile for the good (N=16) readers. The average readers (N=13) were those who fell in between these two percentiles. A subsequent one-way ANOVA yielded an F of 86.60 ($p<.001$); Duncan's Multiple Range Test applied to the means showed that all groups were significantly different from each other ($p<.05$). Comprehension means in order, from poor to good, were: 18.86, 41.61, and 65.25.

Instruments

Measures developed or selected for the study were as follows:

The California Achievement Test. The percentiles from the CAT reading comprehension, vocabulary, mathematics, word problems, and spelling subtests, along with the CAT IQ score were obtained from school records and entered into the data base for the study.

Word Span. Using the Kucera-Francis Corpus as a source (Kucera and Francis, 1967), a pool of high frequency one- and two-syllable words was compiled and used to assemble a conventional word-span test of immediate memory. The test had eight levels; each level consisted of three trials, beginning with three sets of three words each and extending at the last trial to three sets of eight words each. The words were presented serially on slides at the rate of one word per second. Two tests were given; the first was treated as a practice test. The test was scored for the total number of words recalled at each level (word span total) and the last level at which 80% of the words were correctly recalled (word span).

Reading Span. This test had the same format as the word span test, only the stimulus materials were five-word sentences given in set sizes of two to six. It simulated the dual processing load of normal reading comprehension by requiring readers to designate the truth of each sentence presented, while also remembering the last word of each sentence until the end of the trial. The reading span test also yielded a span score and a total score.

Reading Rate. Six short, graded passages selected from high school texts and popular magazines were given as a measure of silent reading rate. Thirty seconds was allowed for each passage, after which students stopped and marked their word positions in the passage. The task was scored for the average reading rate in words per minute over all passages and for total comprehension based on the 24 items in the complete test.

Reading Efficiency. This test consisted of 70 vocabulary-in-context and comprehension items and their attendant passages given in a 40-minute period. Difficulty of the test passages ranged from grade three through college. The reading efficiency score was the number of items correct times the number attempted.

Letter- and Name-Matching. This test assessed speed of access to visual letter forms and letter name codes using a speeded decision task composed of columns of items such as **AA**, **aA**, or **AB**. The letter-match (e.g., **AA** versus **AB**) and name-match (e.g., **Aa** versus **Ab**) items were presented in three sets of 80 randomly ordered items to a page; half the items were negative, half positive. For each page in the test, students were given 30 seconds to mark as many items as they could as either true or false. The test booklet contained three pages each of physical match items, lower case; three of name-match, lower and upper case; and three of physical match, upper case. The letters used to construct the items were A, B, D, E, G, H, N, Q, R and T, each of which has a lower and upper case form that is easily distinguishable.

Scoring was done for the lower case physical-match items and the upper and lower case name-match items. Since different levels of complexity in visual information processing were involved in the two scores, a physical-name match difference score was also calculated.

Synonym Match. This test was composed of six, randomly ordered, 50-item pages of high frequency word pairs; half of the word pairs on each page were synonyms. The first three pages were short, one-syllable word pairs; the second three were three-syllable word pairs. Readers judged as many items on a page as they could as similar in meaning in one minute. The last two pages of each set of three pages in the test was scored for the total number of items attempted and averaged to yield, respectively, the semantic access 1 and semantic access 2 scores. The latter score was subtracted from the former to yield a difference score that was thought to reflect the reader's speed of visual word processing.

The synonym match task provided a measure of speed of access to the meanings of words in long-term memory, an important component in word recognition. This skill was viewed as continuous with the initial stages of word identification that were accessed in the lexical decision task included in the test series.

Lexical Decision. This task was based on the administration of two lists of words, 100 words and 100 nonwords. Half the nonwords were pseudohomophones (e.g., **baik** for **bake**) and half were nonwords that were nonhomonymous but were matched to the pseudohomophones by changing one letter (e.g., **fruke** for **fruit**). A third set of 50 words and nonwords that violated English orthography was also constructed (e.g., **pohf**, **kosd**, **igex**). The words were randomly selected from a master list of one-syllable, high frequency words assembled form the K-F Corpus. Students were given two test forms, each composed of two practice pages and three 50-item test pages consisting of equal numbers of randomly ordered words and nonwords. Readers were given 30 seconds to complete each page in succession, following two 25-item practice pages.

The task was designed as a measure of lexical access time. The homophonous word list, it was expected, would slow performance relative to the two control lists, since phonological encoding would be automatically activated. The difference in time between lists was assumed to represent the time for phonological encoding processes. The tasks thus yielded two lexical access scores and two lexical access difference scores.

Copying Span Task. This task consisted of five brief science passages arranged in roughly equi-distant levels of difficulty, ranging from grade three to grade nine. Passages were presented a sentence at a time for an effective interval of about seven seconds, after which a blank slide was presented. During the blank slide interval, students wrote down as much of the sentence previously presented as they could remember, until at least 10 sentences of each passage had been presented.

Each sentence in a student's protocol for a passage was scored for the number of words recovered in the correct order. The **copy span** score was the proportion of words recounted by a student averaged over all passages in the test. The copy word score was the number of words the student recounted averaged over the sentences and passages in the test. The preferred score in the analyses was the copy span score as this score lacked a problem inherent to the copy word score. This was a low negative or zero correlation between the copy word score for the first passage and the copy word scores for the remaining passages. This result was occasioned by the generally high scores on the initial easy passage in the test.

Word Recoding. A simple measure of phonological recoding skill was obtained by presenting students with 25 words that had been recoded into possible English words (e.g., **baut** for **bought**). Students were allowed three minutes to recode the words into their proper English equivalents.

Procedures

Students were given the foregoing tasks during five class periods of 55 minutes each, interspersed over a period of about one month. Absentees were followed up until complete data were obtained on 43 of the 45 students who initially agreed to participate. Testing was done in intact classes, following the normal schedule for instruction.

Analysis

Because of the experimental nature of many of the tasks used, the data were subjected to extensive preliminary analyses. An initial data reduction phase subjected all variables to descriptive analysis and then to principal components analysis. Subscores for some tasks such as letter- and name-matching were further analyzed using paired-sample t-tests to determine their comparability to the laboratory tasks from which they were derived. Together, the results of these analyses were used to assemble the variables for the principal analyses bearing on the main concerns of the study. These analyses included bivariate correlations of all variables with CAT comprehension scores, discriminant function analyses to determine whether the memory measures discriminated among the reading groups, and one-way and repeated measures ANOVAs to determine whether the groups differed on the chunking measures. A series of planned regressions were also run to clarify the meanings of the memory variables and their contributions to CAT comprehension scores.

Because of the number of analyses and tables involved, only a small portion of the quantitative results are reported here. Principally, these are the bivariate correlations of the independent variables with CAT comprehension and a verbal summary of the findings bearing on the main questions of the study.

Results

Means and standard deviations for the principal subscores and summary scores used in the study are given in Table 1; correlations of these variables with comprehension appear in the right-hand column of the table. With the exception of name match and two of

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Insert Table 1 About Here

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the difference variables--all variables measured in the study were significantly correlated with comprehension. Note that, excluding the name match score, the remaining six untransformed word recognition scores developed for the study were significantly and modestly correlated with reading comprehension (ignoring the difference scores and the redundant averaged scores for the word recognition variables). Spelling, another word processing factor involved in reading, was also correlated at a modestly high level with reading comprehension.

As expected, phonological encoding exerted a modest retarding effect on lexical access; for the difference score 1 comparison, t was 2.79, $p<.008$; for the difference 2 score comparison, t was

5.94, $p<.001$. Name match was also consistently and significantly slower than physical match: t's for the four possible comparisons ranged from 8.35 to 9.74, $p<.0001$.

All three memory variables were significantly correlated with comprehension ($p<.005$); the size of the correlation of the copy span score with CAT comprehension, the chunking measure for the study was especially notable ($r=.762$). The results of the varimax rotation showed word span and copy span were grouped in the first factor, along with verbal IQ, math problems, and reading comprehension. Reading span was included in the second factor, along with semantic access and other measures of lower order language processing speed. The third factor was defined by measures of yet lower order word processing, namely, name and physical match and lexical access.

All three memory variables discriminated significantly among the reading groups in the discriminant function analysis, along with lexical access and semantic access ($p<.001$). The regressions of the independent variables on each memory factor showed that each was accounted for by a different set of variables.

The analyses of the means by passage for the copy word and copy span scores showed all main effects for reading group were significant in the one-way ANOVAs on both scores ($p<.05$). Both the main effects for groups and for passage scores were significant in the repeated measures ANOVA ($p<.05$), indicating not only a reading group effect, but also a systematic decrement in the amount of information recovered over passage difficulty. Multiple comparisons showed that only 4 of 36 possible comparisons of the means for the word and copy span scores were not significant ($p<.05$).

The final regression analyses with comprehension as the dependent variable, using the method, test, in which variables are entered as groups in a prescribed order, again confirmed the importance of the memory variables as a factor explaining differences in reading ability. The final results of this analysis accounted for nearly 75% of the variance in CAT comprehension scores. First, the findings showed that more than 50% of CAT comprehension could be accounted for by letter and other word recognition factors, $R = .732$, $F(9, 33)$, $p<.0001$. The three variables representing memory added approximately another 20% to the variance accounted for in CAT scores, $R = .840$, $F(12, 30)$, $p<.0001$. None of the reading speed variables added significantly to the regression equation; verbal IQ, however, added marginally, $R = .862$ $F(17, 24)$, $p<.0006$.

Discussion and Conclusions

Though the sample for the study is small and nonrepresentative, the findings receive added weight from their consistency with past research using similar measures, mostly with college students (cf. Jackson & McClelland, 1979). The finding of principal interest here is that different measures of working memory differentiated substantially among high school readers differing in reading skill. Moreover, measures of working memory were associated with differences in students' word processing skill. Thus, the findings support the notion that memory limitations in reading are not necessarily inherent but, instead, may reflect reading strategies that are subject to intervention. The results further show that the manner in which working memory is measured may indicate different functional aspects of how memory is involved in reading. Finally, the results relating to the copy span or chunking task suggest an important new method for assessing the reader's capacity for encoding and integrating text at the sentence level. Possibly, the copy span task may be of strategic use in determining suitable text levels for readers differing in comprehension skill.

The study of working memory as it relates to classroom reading may be said to be just beginning. More recent studies have linked memory for phonological codes in young children to vocabulary acquisition (Gathercole & Baddeley, 1989) and to strategies used in discourse processing in mature readers (Engle, Cantor, & Carullo, 1992). The results of the present study are suggestive of a methodology that might be effectively extended to examine working-memory-reading relationships in ecologically more acceptable settings.

References

Baddeley, A.D. (1986). Working memory. Oxford: Clarendon Press.

Daneman, M., & Carpenter, P.A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 19, 450-466.

Engle, R.W., Cantor, J., & Carullo, J.J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 972-992.

Gathercole, S.E., & Baddeley, A.D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. Journal of Memory and Cognition, 28, 200-213.

Kucera, H., & Francis, W.N. (1967). Computational analysis of present-day american English. Providence: Brown University Press.

Lee-Sammons, W.H., & Whitney, P. (1991). Reading perspectives and memory for text: An individual difference perspective. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 1074-1081.

Rothkopf, E.Z. (1980). Copying span as a measure of the information burden in written language. Journal of Verbal Learning and Verbal Behavior, 19, 562-572.

Table 1

Means, Standard Deviations, and Correlations with Comprehension for the principal Scores in the Study

	M	SD	r
IQ	94.58	13.04	.615***
Vocabulary	42.86	22.41	.658***
Math word probs	38.39	18.99	.460***
Spelling	38.81	24.38	.483***
Name match	53.37	9.21	.236
Physical match	69.10	10.92	.434***
Physical/Name	15.64	8.49	.303*
Reading effic	848.91	605.37	.556***
Read rate avge	176.84	50.81	.323**
Read rate comp	67.12	9.08	.335**
Reading span	1.72	1.18	.473***
Reading span tot	34.79	8.46	.448***
Semantic access 1	11.58	3.34	.438***
Semantic access 2	9.27	3.41	.444***
Semantic acc diff	1.09	1.88	.016
Semantic acc avge	10.49	2.80	.533***
Word span	4.86	1.27	.501***
Word span total	74.60	15.04	.407***
Lexical access 1	33.09	6.39	.395***
Lexical access 2	34.25	5.75	.441***
Lexical acc avge	34.80	5.62	.426***
Lexical diff 1	-4.05	9.53	.009
Lexical diff 2	-11.22	12.39	.311**
Word recoding	25.86	11.83	.262*
Copy span	498.09	109.38	.762***
Copy word	6.83	1.57	.727***

*$p<.05$. **$p<.025$. ***$p<.005$, one-tail.