INFORMATION-PROCESSING DIFFERENCES OF COLLEGE-AGE READERS DIFFERING IN READING COMPREHENSION AND SPEED

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ABSTRACT

The present study examined information-processing differences among four types of readers, specifically high comprehension–high speed, high comprehension–low speed, low comprehension–high speed, and low comprehension–low speed college-age readers. Performance was compared on a variety of information-processing tasks, including letter reordering, word reordering, reading span, verification of real words and nonwords, and verification of real sentences and nonsense sentences. Tasks were categorized as lower order tasks involving reaction time and/or elementary-word tasks, or higher order tasks requiring access of word meanings or semantic decision-making. Results indicated that good comprehenders tended to outperform poor comprehenders on all types of tasks. Although high- and low-speed readers performed differentially on some tasks, the pattern of results is less clear. Performance on tasks was discussed in light of speed and comprehension variables and type of information-processing task. Differences in working memory were proposed as a source of individual differences in reading performance.

An approach to the study of individual differences in reading has been to create models focusing on the cognitive processes likely to underlie the act of reading. These models (e.g., Gough, 1972; Just & Carpenter, 1980, 1987, 1992; Kintsch & van Dijk, 1978; Mackworth, 1972; Rubenstein, Garfield, & Millikan, 1970; Rubenstein, Lewis, & Rubenstein, 1971a, 1971b) have sought to interpret the act of reading and explain observed differences in readers from an information processing perspective, describing the internal flow of information throughout the reading process. Information-processing research related to individual differences in reading often has considered one or more of the following cognitive processes:

The construct of working memory has grown out of research that claimed tasks of reasoning, comprehension, and learning share a common memory system related to, but not the same as, the short-term memory (Baddeley & Hitch, 1974). In this view, differences in working-memory processes are not seen as differences in storage capacity, but rather as differences in functional capacity or the efficiency of processes for using short-term capacity. Working memory has limited capacity (Baddeley & Hitch, 1974; Britton, Graesser, Glynn, Hamilton, & Penland, 1983; Britton & Price, 1981; Dempster, 1981). Storage and processing functions compete for the capacity that is available (Baddeley & Hitch, 1974; Case, 1978, 1985, 1992). Less efficient processing of information in working memory (e.g., failing to “chunk” information into larger units, processing very slowly because of inefficient decoding, etc.) will take up more of the total capacity, creating difficulties in the processing of additional information (Just & Carpenter, 1992).

Daneman, Carpenter, and Just (Daneman & Carpenter, 1980; Daneman, Carpenter, & Just, 1982; Just & Carpenter, 1992) have described the possible source of differences between good and poor readers as a trade-off between the storage and processing functions of working memory. In the earlier study, Daneman and Carpenter devised a measure of working memory designed to tax both processing and storage functions in order to test the trade-off between these functions as a source of individual differences in reading comprehension. In this “reading-span task,” participants were given a set of unrelated sentences one at a time and were instructed to read each sentence aloud. At the end of each set, participants were asked to recall the final word of each sentence within that set. The reading-span task was found to correlate more highly with various comprehension measures than previously used short-term memory measures. Masson and Miller (1983) replicated the findings of Daneman and Carpenter on another version of the reading-span task, as well as demonstrating a significant correlation between reading span and the recognition of inferential and explicit statements in text. An implication of these and other studies (Baddeley et al., 1985; Engle et al., 1991; Just & Carpenter, 1992; Turner & Engle, 1989) is that working memory does not function simply as
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temporary storage of text information, but is responsible for processing that information to the degree that coherent relations can be formed and represented in long-term memory. This functional capacity of working memory, resulting from the trade-off between storage and processing ability, may be a significant source of individual differences in the ability to comprehend written text [see Case (1985, 1992) for a discussion of the development and global functions of working-memory capacity]. Most recently, Just and Carpenter (1992) have proposed a theory explaining the way language comprehension is constrained by working-memory capacity. Their “capacity constrained comprehension” theory is “a computational theory in which both storage and processing are fueled by the same commodity: activation. In this framework, capacity can be expressed as the maximum amount of activation available in working memory to support either of the two functions [storage or processing]” (p. 123).

The present research sought to further clarify the relationship between reading comprehension and functional working-memory capacity by examining the performance on a variety of information-processing tasks of readers who differ on the dimensions of reading speed and comprehension. Participants in four groups—high comprehension–high speed (HC-HS), high comprehension–low speed (HC-LS), low comprehension–high speed (LC-HS), and low comprehension–low speed (LC-LS)—were requested to perform tasks designed to represent lower and higher order information-processing tasks, as categorized by Palmer et al. (1985). Lower order tasks were those involving reaction time for the response to a visual stimulus and/or elementary-word tasks, whereas higher order tasks were those that required access of meaning and/or tasks requiring semantic decisions.

In the Palmer et al. (1985) study, reading comprehension and reading speed correlated differently with type of task, with reading comprehension being positively correlated with performance on higher order information-processing tasks and reading speed showing positive correlations with performance on lower order tasks only. The current study tested these findings more directly through the group design (HC-HS, HC-LS, LC-HS, and LC-LS) and the array of tasks selected, which included letter reordering, word reordering, a reading-span task (Daneman & Carpenter, 1980; Masson & Miller, 1983; Turner & Engle, 1989), real-word and nonword verification, and real-sentence and nonsense-sentence verification. In this experiment the letter and word-reordering tasks were judged to be lower order, reaction-time tasks not requiring the access of word meanings or semantic decision-making. Additionally, both reordering tasks were considered measures of working-memory functioning due to the tasks’ demands of simultaneously holding and manipulating incoming information. The reading-span task, also included as a measure of working-memory functioning, was considered a higher order task. Although no semantic decisions were made as part of the reading-span task, participants needed to be involved in the semantic and syntactic processes of reading as they targeted the final word of each sentence for later recall. It should be noted,
however, that, although a measure of working memory, the reading-span task does share methods variance with reading comprehension (i.e., reading and processing of sentences). Therefore, caution must be used in interpreting the typically high correlations found between performance on this task and reading comprehension. Among the verification tasks, the verification of real words and nonwords were considered the most elementary, according to the definition of Palmer et al. (1985), in that the tasks required a response to visual properties of a stimulus, in which the stimuli were words or nonwords. On the continuum from lower to higher order tasks, however, the verification of real words and nonwords were judged to fall somewhere in the middle since participants were required to access meaning to the degree necessary for identification of the set of letters as a word or nonword. The task of verifying sentences as real or nonsense was considered a higher order task involving meaning and semantic decisions. Because none of the verification tasks required the manipulation of information, these were not judged to be tasks assessing working memory functional capacity.

With respect to level of task (Palmer et al., 1985) and the storage versus processing issue (Baddeley & Hitch, 1974; Baddeley et al., 1985; Case, 1978, 1985, 1992), the following predictions were made: Differences based on speed would be found on the lower order elementary-word tasks (real-word and nonword verification) and on lower order tasks not requiring semantic decisions (letter reordering and word reordering). Specifically, within each level of comprehension, differences would be found between the high- and low-speed groups. Differences based on comprehension, regardless of reading speed, would be seen on tasks requiring semantic decisions (verification of real words and nonwords and verification of real and nonsense sentences) and on the tasks requiring participants to hold and manipulate information simultaneously (letter reordering, word reordering, and reading span).

METHOD

Participants

Two hundred undergraduates enrolled in basic educational psychology courses and receiving credit for research participation took a test of reading comprehension (Nelson-Denny Reading Test, Form A) and reading speed. Participants with the top 50 and the bottom 50 raw scores for comprehension were selected out. Each of these groups of high and low comprehenders then were divided into two groups based on their speed scores, high or low. Of the 25 participants included in each group, 16 were randomly selected to participate in the second session of the experiment. One participant was unable to complete the experiment, leaving 63 participants (21 males and 42 females) to take part in the second session. They formed three groups of 16 and one group of 15 participants, representing individuals whose
reading scores fell in the following categories: high comprehension–high speed, high comprehension–low speed, low comprehension–high speed, or low comprehension–low speed. Means, standard deviations, and range scores for reading comprehension and speed are reported for each group in Table 1. Comprehension scores of the low-comprehension groups ranged from the 5th to the 25th percentile, with a median percentile score of approximately 15. The high-comprehension groups ranged from the 68th to the 99th percentile, with a median percentile of 82. Within the high-comprehension groups, reading speed for the high-speed group ranged from 272 to 410 words per minute (\(\bar{x}=310\)) and the reading speed for the low-speed group ranged from 137 to 263 words per minute (\(\bar{x}=227\)). For the low comprehension groups, the reading speed for the high-speed group ranged from 192 to 296 words per minute (\(\bar{x}=231\)) and the reading speed for the low-speed group ranged from 110 to 185 words per minute (\(\bar{x}=159\)).

Table 1

**Group Mean, Standard Deviation, and Range Scores for Comprehension and Speed Variables**

<table>
<thead>
<tr>
<th>Group</th>
<th>Independent Variables</th>
<th>Comprehension</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC-LS</td>
<td>(M)</td>
<td>12.63</td>
<td>23.38</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>1.86</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>9–15</td>
<td>16–27</td>
</tr>
<tr>
<td>LC-HS</td>
<td>(M)</td>
<td>13.88</td>
<td>34.19</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>1.20</td>
<td>4.75</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>11–16</td>
<td>28–44</td>
</tr>
<tr>
<td>HC-LS</td>
<td>(M)</td>
<td>26.20</td>
<td>34.00</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>3.08</td>
<td>4.72</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>24–34</td>
<td>20–39</td>
</tr>
<tr>
<td>HC-HS</td>
<td>(M)</td>
<td>28.75</td>
<td>46.44</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>3.00</td>
<td>6.23</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>25–34</td>
<td>40–62</td>
</tr>
</tbody>
</table>

*Note.* Comprehension means and range scores were based on raw scores of the comprehension section of the Nelson-Denny Reading Test (Form A). Speed means and range scores were based on the number of lines of text read by participants in 90 seconds. Groups were designated by the following abbreviations: LC-LS=low comprehension–low speed; LC-HS=low comprehension–high speed; HC-LS=high comprehension–low speed; and HC-HS=high comprehension–high speed.
Materials and Apparatus

Reading comprehension was tested using the reading comprehension subtest of the Nelson-Denny Reading Test (Form A). Reliability for this subtest was reported as .81 by the test authors (Nelson, Denny, & Brown, 1960). Reading speed was determined using a passage obtained from Newsweek magazine. The passage was typed, double spaced, with the number of each line given in the left margin. The page following the passage contained five questions related to the reading passage. Reliability for the speed measure, assessed by an alternate forms method in which the reading rate scores from the test passage were compared to rate scores on a similar reading passage, was .88. Information-processing performance was assessed with the use of an Apple IIe microcomputer. The computer randomly presented the information-processing tasks and recorded responses and response times for the verification tasks. The experimenter recorded responses on an answer sheet designed for that purpose for the word reordering, letter reordering, and reading-span tasks. Test-retest reliability for the verification tasks was .81 and .63 for the memory tasks.

Procedures

The initial group of participants was tested in several large group sessions on the Nelson-Denny Reading Test (Form A), following standardized procedures for administration. Total number of correct responses was recorded. During the same session, participants were instructed to read the Newsweek passage for 90 seconds with comprehension but yet as rapidly as possible. Number of lines of text read during the given time was recorded. Participants were told they would be asked to answer questions regarding the passage as a means of insuring reading rather than skimming of the material. Responses to questions were not included as data.

Subjects were selected, based on comprehension and speed performance, to participate in a second session of the study. Individual experimental sessions of approximately 1 hour were arranged for each participant during the following 3 to 6 weeks. Within an individual session, participants performed the experimental tasks in randomly selected order under the direction of an experimenter who was blind with respect to group membership.

Information-processing Tasks

Information-processing tasks were programmed and displayed on an Apple IIe microcomputer. Task instructions were presented via the screen, with an experimenter available to answer procedural questions. Practice trials for all tasks ensured participants’ understanding of the procedure; feedback regarding response correctness was not given.

Lettering-reordering task. This task replicated one used in a study of information-processing differences between good and poor writers (Benton, Kraft, Glover,
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& Plake, 1984), which has been posited as a measure of the ability to simultaneously hold and process information and was included for that reason. Participants were presented randomly selected consonants one at a time. Each consonant was projected onto the computer screen for .5 seconds followed by the next consonant. Following the final letter of each set, participants were randomly presented either the instructions “ALPHABETICAL ORDER” or “PRESENTED ORDER” and asked to recall and state orally the letters in the requested order. The random presentation of the instructions to recall letters in either alphabetical or presented order prohibited participants from employing an “on-line” alphabetization strategy while new stimuli was being presented. Participants were given five practice trials consisting of three sets of two letters and two sets of three letters. Test trials consisted of four sets each of two, three, four, and five letters. Half of each set requested the letters to be recalled alphabetically and half in the order presented. The experimenter recorded responses. Each participant obtained a score indicating the number of letters recalled in the correct position for the trials requesting alphabetical order only.

Word-reordering task. The word-reordering task, modeled after the letter-reordering task, asked participants to reorder words rather than letters. Participants were exposed singly to a sequence of up to five words. Each word was presented on the computer screen for .5 seconds followed by the next word. Following the final word participants were instructed to recall the words either alphabetically or as presented, with the particular direction selected at random subject to the constraint that half the time recall was alphabetical and half the time as presented. Practice trials consisted of three sets of two words and two sets of three words. Test trials consisted of four sets each of two, three, four, and five words. Half of each set requested words to be recalled alphabetically and half in the order presented. Each participant obtained a score for the number of words recalled in the correct position for the trials requesting alphabetical order.

Reading-span task. The reading-span task was a variation of the reading-span task conducted by Daneman and Carpenter (1980). Participants read aloud a series of sentences presented one at a time on the screen. As each participant read the last word of each sentence, the experimenter pressed the designated key to present the next sentence. The final sentence was followed by a row of stars, signaling to the participant that they were to recall and state orally, in correct order, the last word of each sentence read. The words stated were recorded by the experimenter. Participants completed five practice trials, including three sets of two sentences each and two sets of three sentences each. The test trials consisted of three sets each of two, three, four, five, and six sentences. Each participant obtained a score indicating the total number of correct final words recalled in the correct location for all test trials.

Real-word and nonword verification. Participants were instructed via the computer screen that they would be presented with a series of words/nonwords, one at
a time, appearing in the middle of the screen. They were instructed to read each word/nonword and respond as quickly as possible, pressing the “Y” key if the item was a real word (e.g., moon, cotton, fruit) and the “N” if the item was a nonword (e.g., zock, erter, strink). Participants were given six practice trials and 40 test trials, 20 each of words and nonwords. Each word/nonword was presented at intervals of 2 seconds following the decision for the previous word/nonword. The computer recorded the number correct for real words and nonwords, as well as reaction time for each response, and calculated the total response time for real words and nonwords separately.

**Real-sentence and nonsense-sentence verification task.** Participants were presented real sentences or nonsense sentences of four to six words in length via the computer screen, one word at a time, and were asked to determine whether the sentence was a real or nonsense sentence. In each case the last word of each sentence determined its sensibility. Speed of presentation was determined by the participant pressing the space bar to bring up each subsequent word. The timing device recorded reaction time, which involved the latency period between when the space bar was pressed to bring up the final word and when the participant pressed “Y” or “N” indicating if the sentence made sense or not. Participants responded to one of two sentence sets of 20 sentences each, 10 real and 10 nonsense. Each set contained the same sentence stems, with only the last word changing between sets. For example, in one set the sentence might read, “Champagne is a beverage,” whereas in the other set it might read, “Champagne is a mammal.” Four sentences were included as practice trials. The computer recorded the number correct for real and nonsense sentences, reaction time for each item, and calculated total reaction time for sentences and nonsense sentences.

**RESULTS**

One-way univariate tests ($p<.05$) were employed to determine if differences existed among the groups for each of the seven tasks. The Tukey-HSD procedure ($p< .0083$) was employed to examine all possible pairwise differences on the dependent variables showing significant univariate effects. Means and standard deviations for all tasks are reported in Table 2. Correlations among the variables are presented in Table 3.

**Letter reordering.** The one-way ANOVA using reading type as the independent variable and the raw scores for letter reordering (number of letters recalled in the correct position for the trials requesting alphabetical order) as the dependent variable showed significant differences between groups [$F(3, 59)=3.72$, $p<.016$]. There was a significant difference between the LC-LS group and the HC-HS group, with the HC-HS group successfully reordering more letters than the LC-LS group.
Table 2

Means, Standard Deviations, and Designation of Pairwise Differences

<table>
<thead>
<tr>
<th>Type of Reading Group</th>
<th>HC-HS</th>
<th>HC-LS</th>
<th>LC-HS</th>
<th>LC-LS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>SD</td>
<td>SD</td>
<td>SD</td>
</tr>
<tr>
<td>Work Memory Tasks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Reordering</td>
<td>21.94</td>
<td>21.33</td>
<td>17.81</td>
<td>16.75</td>
</tr>
<tr>
<td>Reading Span</td>
<td>38.31</td>
<td>35.73</td>
<td>29.38</td>
<td>32.63</td>
</tr>
<tr>
<td>Verification Tasks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Words</td>
<td>7.66</td>
<td>7.70</td>
<td>8.42</td>
<td>9.29</td>
</tr>
<tr>
<td>Nonwords</td>
<td>9.59</td>
<td>10.49</td>
<td>11.55</td>
<td>13.97</td>
</tr>
<tr>
<td>Real Sentences</td>
<td>3.91</td>
<td>3.72</td>
<td>4.18</td>
<td>5.06</td>
</tr>
<tr>
<td>Nonsense Sentences</td>
<td>3.83</td>
<td>3.79</td>
<td>4.41</td>
<td>6.06</td>
</tr>
</tbody>
</table>

Note. HC-HS=high comprehension–high speed; HC-LS=high comprehension–low speed; LC-HS=low comprehension–high speed; LC-LS=low comprehension–low speed. Pairwise differences (p<.0083) are noted by the following superscripts: 1differs from LC-LS group, 2differs from HC-HS group, 3differs from HC-LS group, and 4differs from LC-HS group.

Word reordering. The ANOVA with word reordering (number of words recalled in the correct position for the trials requesting alphabetical order) as the dependent variable detected group differences [F(3, 59)=6.24, p<.016]. There were significant differences between the LC-LS and HC-LS groups, the LC-LS and HC-HS groups, and the LC-HS and HC-HS groups. In each of these comparisons the groups including high-comprehension readers outperformed those groups including low-comprehension readers.

Reading span. The ANOVA using reading-span scores (numbers of correct final words recalled in the correct location for all test trials) as the dependent variable identified group differences [F(3, 59)=4.53, p<.016]. There was a difference between the LC-HS group and the HC-HS group, with the HC-HS group correctly recalling more final words.
Table 3

Correlations between Performance on Tasks and Reading Comprehension and Rate

<table>
<thead>
<tr>
<th></th>
<th>Comprehension</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Working Memory Tasks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter Reordering</td>
<td>0.35**</td>
<td>0.30*</td>
</tr>
<tr>
<td>Word Reordering</td>
<td>0.45***</td>
<td>0.38**</td>
</tr>
<tr>
<td>Reading Span</td>
<td>0.38**</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Verification Tasks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Words</td>
<td>-0.43***</td>
<td>-0.34**</td>
</tr>
<tr>
<td>Nonwords</td>
<td>-0.42**</td>
<td>-0.39**</td>
</tr>
<tr>
<td>Real Sentences</td>
<td>-0.25</td>
<td>-0.25</td>
</tr>
<tr>
<td>Nonsense Sentences</td>
<td>-0.44***</td>
<td>-0.46***</td>
</tr>
</tbody>
</table>

*p<0.05, **p<0.01, ***p<0.001.

Time to verify real words. The ANOVA for time to verify real words indicated significant group differences \([F(3, 59)=7.00, p<.0125]\). Follow-up tests detected differences between the HC-HS and LC-LS groups and also between the HC-LS and LC-LS groups. The LC-LS group took significantly longer to verify real words than both the HC-HS and HC-LS groups.

Time to verify nonwords. The ANOVA with time for the verification of nonwords as the dependent variable showed significant group differences \([F(3, 59)=5.87, p<.0125]\). Group differences were found between the HC-LS and the LC-LS groups, with the HC-LS group taking less time to verify nonwords. Also, the HC-HS group took less time to verify nonwords than the LC-LS group.

Time to verify real sentences. The ANOVA with time for the verification of real sentences as the dependent variable showed no significant group differences between reader types \([F(3, 59)=2.68, p=.06]\).

Time to verify nonsense sentences. The ANOVA with time for the verification of nonsense sentences as the dependent variable showed significant group differences \([F(3, 59)=9.04, p<.0125]\). In the examination of pairwise differences, three groups, the HC-LS, HC-HS, and LC-HS groups, took significantly less time to verify nonsense sentences than did the LC-LS group.
DISCUSSION

Storage versus Processing Functions of Working Memory

Research that has focused on understanding the quantitative and qualitative processes of working memory has documented that working memory has limited capacity (Baddeley & Hitch, 1974; Britton et al., 1983; Britton & Price, 1981; Dempster, 1981) and that storage and processing functions compete for this shared capacity (Baddeley & Hitch, 1974; Case, 1978, 1985, 1992; Just & Carpenter, 1987, 1992). The qualitative differences in working-memory processes that result from the trade-off between the storage and processing functions of working memory have been described as the possible source of differences between good and poor readers (Daneman & Carpenter, 1980; Daneman, Carpenter, & Just, 1982; Just & Carpenter, 1992). One intent of this study was to investigate differences between good and poor comprehenders and fast and slow readers in performance on tasks that required this trade-off of functions. The tasks of letter reordering, word reordering, and reading span were working-memory tasks judged to require participants to hold and/or manipulate incoming information simultaneously and to produce from memory a response that was different from the form in which the information was encoded. Performance differences between groups of different reader types were demonstrated on all three of these tasks.

Letter-reordering task. Using the task categories described by Palmer et al. (1985), the letter-reordering task had been determined to be a lower order task not requiring lexical decisions or the integration of meaning. On this basis, performance differences between high- and low-speed reader groups were expected. However, the only groups performing significantly different from one another on this task were the LC-LS and the HC-HS groups. With this being the only significant pairwise difference, it is not possible to determine which independent variable had the greatest effect on the differences. Benton et al. (1984) demonstrated a relationship between successful performance on this task and good writing skills. By comparing the processing requirements of writing, reading, and letter reordering a possible explanation for why good comprehenders might be successful at this task can be posited. Specifically, a writing model proposed by Linda Flower and John Hayes (e.g., Carey & Flower, 1989; Flower, Schriver, Carey, Haas, & Hayes, 1987; Hayes & Flower, 1986) represents the working-memory processes involved in composing as planning, translating, and reviewing. These aspects of the writing process require the writer to simultaneously hold, analyze, and integrate information into a meaningful representation of knowledge. Similarly, information processing models of reading (e.g., Just & Carpenter, 1980, 1987, 1992) describe analogous processes occurring during reading comprehension. That is, when truly comprehending text material and not just “word calling,” the reading process is highly
interactive, with continuous decisions being made based on the interaction of input and reader knowledge. The reader must integrate words into phrases, relate phrases to each other, analyze phrases within sentences, related sentences to each other, within paragraphs, and to other paragraphs within the total text. Essentially, the processes of holding information, analyzing and manipulating both existing knowledge and new information, and making decisions to arrive at a meaningful whole may be processes common to the tasks of writing, reading, and, in a less complex fashion, letter reordering.

**Word-reordering task.** The word-reordering task also had been categorized as a lower order task that should show differences on the basis of reading speed. The present data did not support this hypothesis, with differences observed consistently only on the basis of comprehension (HC-LS outperforming LC-LS and HC-HS outperforming LC-HS). The word-reordering task was patterned directly after the letter-reordering task, substituting words for letters. It was posited, prior to the experiment, that since there was no need to process the meaning of the words being reordered that the cognitive demands for the two tasks were the same and, therefore, that pattern of results would be similar, that is, differences observed on the basis of both comprehension and speed. One plausible explanation for the present results is that, although the task demands were similar, perhaps participants who were high comprehenders automatically processed the words at a more meaningful level (Craik & Lockhart, 1972; Craik & Tulving, 1975; Jacoby, Craik, & Begg, 1979), resulting in a stronger memory trace that allowed the words to be remembered and recognized more effectively. It is possible that the stronger memory trace, resulting from more meaningful processing (Craik & Tulving, 1975), would allow high comprehenders to then recall, rearrange, and present the words in the requested order more successfully. Since this was a task that had not been tested or discussed in the literature, further investigation is warranted to more clearly understand how it is related to reading and other information-processing tasks.

**Reading-span task.** Although significant group differences were found only between the HC-HS and the LC-HS groups on this task, this pattern reflects the results obtained by Daneman and Carpenter (1980). It was predicted that performance on this task would differ between groups differing in reading comprehension, but not between groups differing in reading speed. This task relies heavily upon short-term memory and the ability to hold information while new, conflicting information is being introduced. One possible explanation is that high comprehenders are better able to do this because content is processed at a more meaningful level (Craik & Lockhart, 1972; Craik & Tulving, 1975; Jacoby, Craik, & Begg, 1979). This meaningful processing may enable high comprehenders to recall enough of the gist of each sentence to cue the final word. Low comprehenders, who may not be constructing as meaningful a framework as they read, may not be able to recall the gist of the sentence or idea unit to use as a cue for remembering. However, an explanation consistent with the capacity constrained comprehension
theory (Just & Carpenter, 1992) is more appealing.

As stated earlier, the reading-span task was designed to require the simultaneous use of processing and storage functions of working memory. Just and Carpenter (1992) explain that high-span readers should consume less of the working-memory resources than low-span readers, leaving more capacity for remembering the final words of sentences. The constrained capacity is reflected in the "trading relation between the performance of the two tasks when they are done simultaneously" (p. 125). This task shows performance differences between good and poor comprehenders because the task demands exceed the available supply of resources. Just and Carpenter also offer an explanation as to why the reading-span measure did not correlated significantly with reading speed. They state, "For easy texts, low span subjects read only marginally slower than high span subjects but on particularly difficult portions of a text, low span subjects tend to be substantially slower than high span subjects" (p. 125). The text used to determine reading speed for this study was one that would not pose particular difficulty for most college-age readers. Consequently, the low correlation between reading rate and reading span performance (\(r=0.22\)) is understandable.

Comprehension and Speed as Sources of Individual Differences

One of the basic questions addressed in this study was whether reading groups varying in speed and reading comprehension would differ in performance on a selected set of information-processing tasks. Jackson and McClelland (1979), for instance, have suggested that reading speed and comprehension are empirically distinguishable. The high correlation they found between reading speed and comprehension indicated that the participants who were reading faster also tended to be comprehending more accurately. At the same time, however, Jackson and McClelland found that the processes that correlated with reading speed were not correlated as highly with comprehension and posited that different processes influence individual differences in reading speed than influence individual differences in reading comprehension. Similarly, the work of Palmer et al. (1985) led to the prediction that high-speed readers, no matter what their level of comprehension, should outperform low-speed readers on lower order tasks and that both fast and slow high-comprehension readers should perform better on the higher order tasks than low-comprehension readers. Although it may be true that different process may influence differences in reading comprehension than influence differences in reading speed, the present study did not conclusively support this. However, on the lower order task not requiring semantic decisions (letter reordering) and on the time to verify real words, nonwords, and nonsense sentences, a consistent pattern of pairwise differences was noted. On all of these tasks the HC-HS group performed significantly better than the LC-LS group. These results indicate that speed, as well as comprehension, is a variable affecting performance on these tasks. When pairwise differences in performance were noted (as they were on all tasks except
verification of real sentences), the high-comprehension groups consistently outperformed the low-comprehension groups.

It should be noted that, due to the method of subject selection, the differences between the reading-speed scores of the high and low comprehenders were not as different as the reading-comprehension scores were between the high- and low-speed readers. In forming groups, participants were first selected based on comprehension (high and low) and then sorted into high- and low-speed readers at the two levels of comprehension. A specific example of how this minimizes speed differences between groups is seen when comparing reading speed of the low comprehension–high speed group with the high comprehension–low speed group on speed. These two groups are very similar in terms of means and standard deviations on the speed measure (see Table 1). Although differences in speed are noted between the two high-comprehension groups and the two low-comprehension groups, the low comprehension–high speed and high comprehension–low speed comparison indicates that the low speed of high comprehenders is similar to the high speed of the low comprehenders. This similarity may have resulted in the inability to determine processing differences between the reading-speed groups. Although this make-up of groups may have contributed to the inability to obtain conclusive results, the comprehension-speed patterns reflected in these groups are a likely portrayal of “real-life” readers. Specifically, it is logical to assume that the high speed of poor comprehenders would not be as high as the high speed of good comprehenders. Furthermore, it is not surprising that slow, good readers read at a rate similar to fast, poor readers.

An investigation of differences of task requirements within this study and between studies investigating similar issues provides additional explanation for the obtained outcomes. In looking at the word-verification task, it was noted that the results were not consistent with the hypothesized results, nor did they replicate those of the Palmer et al. (1985) study, where it was found that elementary-word tasks were related primarily to reading speed. Palmer et al.’s lexical decision task differed from the current word-verification task in that participants in the Palmer et al., study were presented two words consecutively, with each item requiring a response. The pairs consisted of associated words, nonassociated words, and nonwords. In contrast, single words and nonwords with no association were presented singly in the present experiment. It may be that the Palmer et al., word-identification task required more variables to be considered when making the lexical decision, causing a heavier burden on information stored in long-term memory regarding the orthography and meanings of individual words. The ability to access this information rapidly may be a variable related to reading speed. When the task was simplified, however, as in the present experiment, and the demands on long-term memory were reduced, performance differences were seen only between the HC-HS and LC-LS groups and the HC-LS and LC-LS groups.

An investigation of task requirements for the sentence-verification task also provides a possible explanation of performance patterns. The sentence-verification
task in this study involved sentences that were simple in terms of both structure and content (e.g., A collie is a dog). The task required participants to make decisions on semantic knowledge assumed to be common to all participants, with the critical component being the amount of time taken to make the decisions, indicating the speed of access of the critical information and processing time. All types of readers apparently accessed the needed information similarly, regardless of their ability to comprehend or their reading speed, when the match was a real or sensible fit.

The pattern of results for verification of nonsense sentences was similar to the pattern for nonwords. The LC-LS readers took significantly longer than HC-LS, HC-HS, and LC-HS readers to perform this task. An explanation for this might involve a lack of ability of the LC-LS readers to retrieve requisite information necessary from long-term memory into working memory, sort through the information related to words, sentences, and so on, and come up with an accurate decision in a timely fashion. This data does not indicate whether low comprehension or low speed contributed more significantly to this group’s lower performance.

Conclusion

As researchers have explored the cognitive processes that occur during the act of reading, it has become increasingly clear that comprehension occurs as a result of the interaction of incoming information, or the printed text, and the reader’s network of knowledge in long-term memory (e.g. Adams & Collins, 1977; Just & Carpenter, 1987; Kintsch, 1986; Kintsch & van Dijk, 1978; Rumelhart & McClelland, 1981). Working memory has been referred to as the “cognitive workbench” (Britton, Glynn, & Smith, 1985), whose function has been to deal with this interaction of incoming and existing information. The results of this study of individual differences in reading supported the conclusion that the quality of the processing that occurs in working memory is different for good and poor comprehenders, with processing differences between fast and slow readers being more difficult to substantiate. Perhaps, as suggested by Just and Carpenter (1987), reading speed is one facet of the multidimensional skill of reading that affects and is related to comprehension, but is not a process that can be separated and examined in isolation. Attempts should be made to further investigate these working-memory processes and how these processes function during the act of reading.

REFERENCES


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