International Journal of Literacy and Education

E-ISSN: 2789-1615
P-ISSN: 2789-1607
Impact Factor: 5.69
IJLE 2024; 4(1): 27-35
www.educationjournal.info
Received: 02-11-2023
Accepted: 03-12-2023

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Local level processing and working memory capacity in text modeling: The case of low and high literate adults

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DOI: https://doi.org/10.22271/27891607.2024.v4.i1a.161

Abstract
Verbal Efficiency Theory is drawn upon to explain differences in reading processes between low and high-literate adults. This experimental study investigates local and higher-order text reading processes and working memory capacity when the literacy level varies. This research finds that low-literate adults report much more inefficient local and text-reading processes than high-literate adults. As text difficulty increases, this discrepancy widens more drastically. Working memory capacity is a critical mediator in explaining the relationship between local and text-reading processes.

Keywords: Low literate adults, verbal efficiency theory, working memory capacity, text modeling

1. Introduction

Word-level reading and text-level reading are considered two fundamental processing components of reading (van Viersen, Protopapas, & de Jong, 2022) [1]. Verbal Efficiency Theory (Perfetti, 1983, 2007) [2, 3] claims that individual differences in reading ability are the source of inefficient local (word level) text processing, which impacts text-model processing due to working memory constraints after local text processing. Efficient local reading processing is vital for text comprehension and sources of differences between good and poor readers (van Viersen, Protopapas, & de Jong, 2022; Zarić, 2021) [1, 4].

VET incorporates that readers' cognitive systems operate under limited cognitive capacity. Thus, when limited cognitive capacity is used up for inefficient local reading processes, there will be less room for text-model processes. The notion of working memory (Baddeley & Hitch, 1974; Nouwens, Groen, & Verhoeven, 2017) [5-6] is the critical element that drives verbal efficiency. For low-literate readers, the smaller working memory capacity due to inefficient local reading processing may influence the comprehension process. In contrast, larger working memory capacity due to efficient local reading processing may result in better comprehension for high-literate readers.

Thus, the current study investigates how low-literate adults perform local and text modeling processing compared to high-literate adults and how reading inefficiency among low-literate adults will become more pronounced as text difficulty increases. The study also examines the role of working memory capacity as a mediator concerning local and text modeling processes, which has received little attention in the literature. The following section presents a literature review and hypotheses summarizing individual differences in reading ability at the word and text levels and the relationships between the reading process and working memory.

2. Literature Review and Hypotheses Development

2.1 Word Level Processing

Various studies have explored local reading processes to test whether good readers were efficient at local text processing. Good readers tend to have greater vocabulary knowledge, which enables them to process more efficiently at the word level (Lewellen, Pisoni, & Greene, 1992, van Viersen, Protopapas, & de Jong, 2022; Zarić, 2021) [7, 1, 4]. Past research shows that differences in word decoding (oral accuracy and reading rate) account for much of the variance between good and poor readers in children (Third grade) as well as in adult basic-literacy students (Bristow & Leslie, 1988; Pratt & Brady, 1988; Greenberg, Ehri, & Perin, 1997) [8-10].

When basic reading and spelling skills are tested, adults with reading skills at the fifth-grade level or below remain poor readers despite general cognitive maturity, experience with written language, and adequate general intelligence (Read & Ruyter, 1985) [11]. They display poor skills in word decoding on oral accuracy tests (the ability to relate the printed word to pronunciation). Adults at the fifth-grade level or below reading have greater difficulty pronouncing words (real and pseudo-words) than even children who are poor readers. The percentages of correct answers on the decoding skill test show that decoding accuracy worsens when participants read pseudo-words.

Rapid word recognition is another known characteristic of good readers (Perfetti, Goldman, & Hogaboam, 1979; Stanovich, 1980) [12-13]. Besides oral reading accuracy and comprehension level, reading speed was an essential indicator of difficulty for adult basic literacy students who read below the sixth-grade level (Bristow & Leslie, 1988) [8]. Even among college students, good readers are consistently faster in naming stimulus words regardless of the frequency of words and word length (Lewellen, Goldinger, Pisoni, & Greene, 1993) [7]. Efficient college readers showed a small performance (speed and accuracy) decrease when they were shown words with different frequencies, but less-skilled readers showed a significant performance decrease in naming tasks (Herdman & LeFevre, 1992) [14].

2.2. Text- Modeling Processes

In text-level reading processes, poor readers tend to display lower comprehension of text than good readers (Bell & Perfetti, 1994; Cunningham, Stanovich, & Wilson, 1990; Sabatini, 2002; Viersen, Protopapas, & de Jong, 2022) [15-17, 1]. This finding is due to poor readers' inefficient local text processing, which impacts poor readers' comprehension (Bell & Perfetti, 1994; Jenkins *et al*., 2003) [15, 18]. Skilled readers are known to have better comprehension skills than less skilled readers regardless of text type (science, history, and fiction) or passage length (Bell & Perfetti, 1994) [15]. Under longer passage lengths, less-skilled readers showed more significant discrepancies in reading speed and comprehension skills. Less-skilled readers read longer passages much more slowly than skilled readers, and this discrepancy increased as skills decreased. The impact of reading skills also applies to comprehension of instructional material (procedural knowledge) and narrative text (LeFever, 1988) [19]. Thus, the inefficiency of local text processing for low-literate readers should impact text-modeling processing regardless of text type. When the readability of text decreases, the ability to comprehend will diminish to a greater extent among low-literate participants.

2.3. Working Memory and Reading Ability

In text comprehension, readers who are efficient at processing information (reading at the local level) will benefit because they have more storage space left for text comprehension. The idea of working memory explains why inefficient local processing leads to poor text comprehension. Perfetti (1985) [20] claims that inefficient local text processing leaves less working memory capacity that can be devoted to text-modeling processes. Working memory is a limited capacity system that emphasizes storing and processing information (Baddeley & Hitch, 1974; Daneman & Carpenter, 1980; Nouwens, Groen, & Verhoeven, 2017) [5, 21, 7]. Working memory capacity is measured by accessing the efficient use of both processing and storage of information (Daneman & Carpenter, 1980) [21]. According to Daneman and Carpenter's (1980) [21] conceptualization of working memory in language comprehension, individuals with small working memory capacity devote so many resources to reading processes that they have less residual capacity for retaining relevant information in working memory. Thus, after poor readers finish the local text reading process, they will have less working memory capacity to integrate the whole text than good readers. Because poor readers spend most of their resources processing the information at the local level, they have less storage capacity left for the text-comprehension process.

Existing studies show that local text processing is a significant predictor for the text-modeling process, confirming the notion of VET. Word decoding significantly predicts reading comprehension among college students (Cunningham, Stanovich, & Wilson, 1990) [16]. Similarly, Bell and Perfetti (1994) [15] show that reading speed and vocabulary knowledge significantly predict reading comprehension. Though there were no directional relations, the studies by Golinkoff (1975-1976) [22], Bristow and Leslie (1988) [8], and Cupples and Holmes (1992) [23] indicate that local text processing was significantly related to text-modeling processing. Though these studies did not investigate the role of working memory capacity, VET suggests that working memory capacity will mediate the reading process between local and text processing. Thus, the study predicts that local text processing will lead to text comprehension, which will be mediated by working memory capacity. Based on the literature review, the following hypotheses are offered.

H_1: Relative to high-literate adults, low-literate adults will (a) be less able local processors and (b) display lower text comprehension.

H_2: The extent to which low-literate adults will (a) be less able local processers and (b) display lower text comprehension than high-literate adults as text complexity increases.

H_3: The (a) direct and (b) interactive (with text complexity) effect of local processing on text comprehension will be mediated by verbal working memory capacity.

3. Materials and Method

3.1 Design and Sample

The design of the study is 2 (literacy level: low and high) X 3 (reading difficulty: easy, medium, and difficult). Reading difficulty is a within-subject factor. Local text processes examined the efficiency of word decoding (oral accuracy and reading speed). For the current study, text- modeling process examined reading comprehension.

Participants were recruited from two sources. For the low-literate level, adult learners from various local adult education centers were recruited (n = 28). The adult learners recruited are all native English speakers. These centers offer three types of classes: literacy classes in which the level of reading ranges from grade zero to below sixth grade, pre-GED classes in which the level ranges from sixth to eighth grade, and GED classes in which the level ranges from ninth to twelfth grade. For the current study, we recruited adult students from literacy classes. Adkins and Ozanne (2005) [24] suggested that the lowest two literacy groups possess below sixth-grade-level reading and math skills based on the 1992 National Adult Literacy Survey.

However, the studies by Adkins and Ozanne (2005) [24] and Viswanathan, Rosa, and Harris (2005) [25] also included GED students (ninth- to twelfth-grade level) for functionally or low-literate adults. Considering no known objective standard for distinguishing between low- and high-literate adults, the sixth-grade reading level was used as the cut-off point for low-literate adults. Adult learners with zero to below-sixth-grade reading levels were recruited as low-literate readers. Each recruited subject was paid $30 for participating in the study.

Participants from the local university who scored above the ninth-grade level were considered high-literate adults (n = 28). The ninth-grade level was chosen because the typical GED class requires a minimum ninth-grade level for reading and math skills. Since all university students possess high school diplomas, we expected them to have reading levels higher than the minimum requirements of a GED class. Participants were recruited from the research subject pool of the local university. Each subject received two research credits for participating in the study.

To discriminate between the two groups by their literacy level, we used two measures to assess their reading level. The first was a 13-item self-report language proficiency scale developed by Luna and Peracchio (2001) [26]. Each item has five 5-point scale (not very good/ very good for the first four items, very bad/very well for the next nine items). The other was an objective, standardized test called the

Reading level indicator test

A Quick Group Reading Placement Test by AGS Publishing (2000) [27]. The test comprises twenty vocabulary and twenty sentence-comprehension multiple-choice questions.

3.2 Procedure for testing local processing

Individual participants were greeted and told they would be tested in a reading assessment. At Time 1, they completed a 13-item self-report language-proficiency scale (Luna & Peracchio 2001) [26] and took the Reading Level Indicator Test (2000) [27] containing vocabulary and sentence comprehension questions. At Time 2, participants were told that part of their reading test would be audiotaped. This session included a total of four procedures. Participants took the speed and oral accuracy tests, text-comprehension test, and listening span for working memory-capacity test. They also answered demographic questions. A digital watch and audio recorder were present in the room. Each reading test was administrated individually.

First, the local text process investigated speed and accuracy using the list of words taken from the Group Reading Assessment and Diagnostic Evaluation (2001) [28]. To administer the assessment, we gave the following directions (Jenkins *et al*. 2003) [18].

I want you to read the words on these pages to me. Try to read every word. Do your best. When I say, "Begin," read the words out loud. You'll have one minute to read as many words as you can. If you wait too long to say a word, I'll tell you the word. Then keep reading. You can skip words you don't know. If you come to the end of the page, turn to the next page. At the end of one minute, I'll say, "Stop." Do you have any questions?

This simple measurement procedure has been used extensively in over a hundred studies (Jenkins *et al*. 2003) [18]. We used a digital countdown watch to measure one minute while audiotaping participants' reading. Once this procedure was finished, participants were asked to do the second task.

3.2.1 Measures

Speed of Word Reading

The procedure by Jenkins *et al*. (2003) [18] was used to measure the speed of word decoding, which calls for recording the number of seconds per correct word. The formula is one divided by words correct divided by 60. A digital countdown stopwatch was used to measure the one-minute time limit.

Accuracy of Word Reading

The procedure by Jenkins *et al*. (2003) [18] was used to measure accuracy of word reading. Based on voice recordings of participants, accuracy was measured as follows: words read correctly divided by total words read. Word reading errors included omissions, insertions, mispronunciations, substitutions, and hesitations of more than three seconds (as an operationalization of "waiting too long"). Self-corrections were not recorded as errors. Regional or racial dialects were not considered errors in the accuracy testing, as recommended by Bristow and Leslie (1988) [8]. Inter-score agreement by two coders was used to check the reliability of the measurement. The score was calculated as a number of agreements divided by agreements plus disagreements.

3.2.2 Stimuli

The stimulus material included three-word lists taken from the Group Reading Assessment and Diagnostic Evaluation (2001) [28]. The standardized testing comes with varying levels that include vocabulary and passage-comprehension testing (levels 1, 2, 3, 4, 5, 6, M, H, and A). The three lists with different difficulty levels were chosen for the vocabulary-testing sections: easy (third- and fourth-grade reading levels), medium (medium and high reading levels), and difficult (adult reading level). The number of words in each list ranged from 110 to 240.

3.3 Procedure for testing text-modeling process

Text-modeling processing deals with understanding the overall meaning of extended text, thus assess reading comprehension. Participants were asked to answer multiple-choice questions after they read each passage. No time limit was imposed on this particular test; participants answered the questions at their speed.

3.3.1. Measures

Reading Comprehension

Each passage included questions on literal comprehension of the passage (The answers are directly stated in the passage). As the passage increased in reading difficulty, questions included inferential comprehension (The answers were not directly stated in the text, and integration of knowledge from reading the passage was required). The number of answers correct on the comprehension test of each passage was measured.

3.3.2 Stimuli

The stimulus material included six passages and twenty-four multiple questions (four questions per passage) taken from the Test of Adult Basic Education (1992) [29] and Group Reading Assessment and Diagnostic Evaluation (2001) [28]. Six reading passages with different difficulty levels were chosen: easy (third- to fourth-grade reading level), medium (sixth- to seventh-grade reading level), and difficult (eleventh to twelfth). The reading difficulty of the passage was also verified by the readability index of Microsoft Word's Flesch-Kincaide Grade Level. To avoid having the participants guess the answers without reading the actual questions, a pretest of text-processing comprehension questions was conducted.

The 24 multiple-choice questions and six reading passages for text comprehension were selected from the standardized testing materials (Group Reading Assessment and Diagnostic Evaluation 2001; Test of Adult Basic Education 1992) [28-29]. To avoid having the participants guess the answers without reading the actual questions, all comprehension questions were examined to see how well participants could guess the answers. Participants (n = 10) were given all 24 multiple-choice questions without the corresponding passages. Of 24 questions, five questions were answered correctly by more than five of the participants without reading the passages. Those questions were revised and retested with a different set of participants (n =10) to examine whether they could still guess the answers. Not one of the 24 questions was guessed by more than five participants on the second pretest.

Last, all questions and the passages were given to a new set of participants (n = 14) to examine the difficulty level of the text materials. One-way ANOVA was employed to test the comprehension difference among three difficulty levels of the text (easy, medium, and difficult). Text difficulty was a within-subject factor. There was a main effect of text difficulty, F (1, 13) = 14.560, $p< .01$. The contrast tests reveal that participants scored significantly higher comprehension rates in reading easy text than in reading the medium text (means of 7.71 versus 7, t = 2.34, $p< .05$). Participants also scored a significantly higher level of comprehension in reading medium text than in reading the difficult text (means of 7 versus 5.71, t = 2.53, p< .05). Thus, the difficulty level among text (easy, medium, and difficult) held after the questions were modified.

3.4 Procedure of testing working memory

Working memory-span tasks were administered to test the working memory capacity of participants. VET assumes that working memory is limited in capacity; thus, inefficient verbal encoding leaves less capacity for text-modeling processing. Reading-span tests will assess readers' ability to recall words while encoding verbal materials in working memory. Daneman and Carpenter (1980) [21] demonstrated that the listening-span test is as equally effective as the reading-span test in predicting reading comprehension. Bell and Perfetti (1994) [15] used both reading- and listening-span tasks for working memory tasks. Both good and poor readers demonstrated better performances on listening-span tasks than on the reading-span task.

For the current study, the listening task was more appropriate for assessing working memory due to the low reading ability of low-literate participants. The material and procedures were adopted from Cherry and Park (1993) [30]. Participants listened to an audiotaped voice reading sentences from two to six of them. Then, participants were asked to recall the last word of each sentence in the set. Memory span was measured as the number of last words in a sentence that were recalled correctly and consistently. The following directions were given, as adopted from Daneman and Carpenter's (1980) [21] listening-span test.

You are going to listen to a list of sentences. You are going to listen to one sentence at a time. At the end of each sentence, I am going to pause briefly before I go on to the next sentence. After you listen to the sentences, I am going to ask you to remember the last words of each sentence. I am going to start with three sentences in each set. But as I go on, the number of sentences you are going to listen to will increase. This is a difficult test so try to concentrate, and don't get discouraged if you cannot remember all the words. Ready?

3.4.1 Measures

Listening Span Test

Daneman and Carpenter's reading-span test (1980) [21] was highly correlated with reading comprehension (r = .84). The meta-analysis by Daneman and Merikle (1996) [31] also supported that testing working memory by testing processing and storage capacity (reading span and listening span) predicts comprehension better than using measures that detect only storage capacity (word span, digit span).

The listening-span test measures working memory capacity (Bell & Perfetti 1994; Daneman & Carpenter 1980) [15, 21]. The listening-span test contains three sets of the following: two, three, four, five, and six sentences. Participants listened to increasingly longer sets of sentences. Memory span is "the number of last words in a sentence that can be consistently recalled" (Bell & Perfetti 1994, p. 246) [15]. For the current study, the working memory span for this test was calculated as the number of last words correctly recalled.

3.4.2 Stimuli

The material from Cherry and Park (1993) [30] was adopted. There were sixty unrelated sentences, thirteen to sixteen words in length. Each sentence ended with a different word. Each set contained three sets of two, three, four, five, and six sentences. To avoid simple memorization of the last word by participants, the test included random verbal questions every three or four sentences to make sure all participants processed the content of the sentences. The 60 sentences were also tested to ensure that the reading level did not reach too high for low-literate participants. Sixty sentences used by Cherry and Park (1993) [30] were modified to measure working memory span. The readability of some sentences was higher than the eighth-grade level. Thus, the sentences were modified using simpler words to set them below the eighth-grade level, and all the sentences were retested against Microsoft Flesch-Kincaid Grade Level to ensure the sentence readability was not too complex for low-literate participants.

After the 60 sentences were modified, a list of the last words of each sentence was prepared to investigate whether low-literate participants were familiar with those words. Since the task for testing working memory capacity is to recall the last word of the sentence the participants hear, we wanted to be certain that the low-literate participants would be familiar with the words when they heard them. In the participants' reading class, the reading tutor read aloud the list of randomly assembled 60 words (last word) to 7 low-literate participants. They were asked to report any words they were not familiar with. The tutor conducted this task to avoid any embarrassment low-literate students might have if they had to admit that some words were unfamiliar. All reported that they were familiar with the words presented.

4. Results and Discussions

The high-literate participants were significantly younger (means of 21.89 vs. 44.94, $t = -10.46$, $p < .01$) than the low-literate participants. Their education level was also significantly higher than the low-literate participants ($\chi2 = 38$, $df = 4$, $p < .01$). For both high- and low-literate groups, the sample (78.9% and 68.4%) comprised a dominant proportion of Caucasians. African Americans comprised 21.1% and 31.6% of the high-literate and low-literate groups, respectively. However, there was no significant association between literacy level and race ($\chi2 = .543$, DF = 1, $p > .05$). Gender composition was relatively even in ratio. A slightly higher number of female participants participated (52.6% for high-literate and 57.9% for low-literate groups). Male participants comprised 47.4% and 42.1% of high and low-literate groups. Again, there was no significant association between literacy level and gender ($\chi2 = .106$, DF = 1, $p > .05$).

4.1 Language Proficiency Scale and Reading Level Indicator

To verify the literacy levels of the participants (high versus low), the present study used two scales. The Language Proficiency scale is a 13-item subjective scale measuring individuals' subjective perception of language skills, including general language skills such as reading, writing, speaking, and comprehending English and functional language skills such as understanding cooking directions, reading novels, writing advertisements, etc. (Luna & Peracchio, 2001) [26]. Each item has a 5-point response (not very good/ very good for the first four items, very bad/very well for the next nine items). The other was an objective, standardized test, the Reading Level Indicator Test: A Quick Group Reading Placement Test, by AGS Publishing (2000) [27]. It includes 20 multiple-choice questions on sentence completion and 20 multiple-choice questions on vocabulary. The raw score of the reading level indicator was converted to the reading grade level. The language proficiency scale was highly reliable (alpha = .940), and the correlation with the reading level indicator was significant (r = .583 $p < .01$ for raw score, r = .629, $p < .01$ for grade level score).

The series of t-tests show significant differences between low- and high-literacy participants in the language proficiency scale ($t = 4.57$, $p < .01$), in the reading level indicator raw score ($t = 10.39$, $p < .01$), and in the reading grade level ($t = 27.85$, $p < .01$). The reading grade levels for all high-literacy participants were over 9.7. The low-literate participants ranged from grade 1.9 to grade 5.8, with a mean grade level of 3.32. The results clearly distinguish between high- and low-literate participants in language skills. However, it is noticeable that the reading grade raw score had a relatively large gap (50% difference for the raw score), but the language proficiency scale showed only 20% difference between low- and high-literacy participants.

Coefficient of Variation (Sheskin, 2004) [32] revealed that low-literate participants displayed 519% more variation than high-literacy participants in their language proficiency scale score, and low-literate participants displayed 788% more variation than high-literacy participants in their reading level indicator test. Low-literate participants were more optimistic about their language proficiency skills when asked to report their subjective perceptions of language skills. However, the reading level indicator may have revealed a more accurate measure of their actual reading skill. Speed was operationalized as the number of seconds to read each correct word. The formula was one divided by words correct divided by 60 (Jenkins *et al*. 2003) [18].

4.2. Hypotheses Testing

Data from nine low-literate participants were not included because the participants' reading levels were either too low (below the first-grade level) or too high (above the ninth grade). Ultimately, usable data from 19 low-literate participants, displaying reading abilities from the second to sixth grade (mean = 3.2), is included. All 19 participants in the high-literacy group had a reading grade level over the ninth grade (mean = 11.2). Scores on the language proficiency scale ($\alpha = .940$, $t = 4.57$, $p < .001$) and reading level indicator ($t = 10.39$, $p < .001$) further confirm that the samples display different levels of reading proficiency.

Mixed MANOVA (General Linear Model Repeated Measures) was employed to investigate speed, accuracy, and text comprehension as dependent variables. The three dependent variables displayed high correlations among each other (r > .7); thus, MANOVA usage was justified. MANOVA revealed that there were significant main effects of literacy, F (3, 34) = 39.972, $p < .01$, and text difficulty, F (3, 34) = 39.972, $p < .01$. There was a significant interaction effect between text difficulty and literacy, F (6, 31) = 35.512, $p < .01$. To investigate the proposed hypotheses, the univariate results for each dependent variable were examined.

Mixed ANOVA using GLM assessed the study data. Consistent with H1a, there was a significant main effect of literacy on the speed of word processing (F (1, 36) = 27.29, $p < .001$) as it took longer per word for low-literate processors to read than it took high-literate processors (*M* low-literate = 9.59 sec. versus *M* high-literacy = 0.80 sec., $t = 5.22$, $p < .001$). For the accuracy measure, interscore agreement by two coders was used to check the reliability of the measurement. A sample of 20% (out of the total data) was used to calculate the number of agreements divided by agreements plus disagreements. Two coders reviewed data that was randomly selected (four participants from the high-literate group and four participants from low-literate group). The results demonstrated that inter-score agreement reached 90%. Low-literate participants reported less accurate reading when they read the list of words than high-literacy participants (means of 62.60 versus 97.7, $t = 11.12$, $p < .01$). The percentage of words read correctly was much lower for low-literate participants than it was for high-literate participants. Thus, Hypothesis 1a is supported.

There was also a main effect of literacy on text comprehension, F (1, 36) = 102.53, $p < .001$), as high-literate participants showed a higher number of correct answers for the text comprehension measures than did low-literate participants (*M*high-literacy = 60.78 versus *M*low-literate = 35.19, $t = 10.12$, $p < .001$). Thus, Hypothesis 1b is supported.

Table 1: Means (Standard Deviations) for Reading Speed, Accuracy, and Comprehension

	High Literacy (n=19)				Low Literacy (n=19)			
	Easy	**Med.***	**Diff.***	**Total***	**Easy**	**Med.**	**Diff.**	**Total**
Text Comprehension Means (number) (SD)	23.68 (.94)	21.47 (3.50)	15.63(5.0)	60.78 (7.13)	17.67 (4.84)	12.31 (4.78)	5.21 (2.61)	35.19 (8.4)
Speed Means (seconds) (S.D.)	.57 (.13)	.72 (.11)	1.12 (.31)	.80 (.16)	1.51 (.78)	3.84 (2.36)	23.42 (19.5)	9.59 (7.33)
Accuracy Means (%) (SD)	99.8 (.46)	99.4 (.75)	93.9 (5.0)	97.7 (1.8)	86.2 (16.1)	65.3 (19.0)	36.27 (18.9)	62.60 (13.6)

There was a significant interaction between literacy and text complexity on the speed of word processing (F (2, 72) = 22.99, p< .001). As text complexity increases, the reading speed of low-literate participants decreases significantly (*M*easy = 1.51 sec. versus *M*medium = 3.85 sec., t = 8.07, p< .001, *M*medium = 3.85 sec. versus *M*difficult = 23.42 sec., t = 6.81, p< .001). Thus, low-literate participants displayed a 154% increase in reading time when going from easy to moderate text and a 508% increase going from moderate to difficult text. High-literate processors displayed significant but less dramatic speed changes across the three complexity levels as reading time increased 26% between the easy and medium text (*M*easy = .57 sec. versus *M*medium=.72 sec., t = 8.4, p< .001) and 55% between the medium and difficult text (*M*medium = .72 sec. versus *M*difficult = 1.12 sec., t = 7.02, p< .001). An interaction of the text difficulty by literacy group was revealed on the accuracy, F (2, 72) = 41.986, p< .01. The high-literate participants did not show significant decreases in their accuracy among three levels of difficulty (easy versus medium: means of 99.78 versus .99.36, t = .57, p> .05, medium versus difficult: means of 99.36 versus 93.87, t = 1.40, p>.05). For low-literate participants, as text difficulty increased, the percentage of words read correctly decreased significantly greater, while high-literacy participants held steady accuracy ratings. Low-literate participants showed significantly higher accuracy ratings at the easy level than at the medium level and significantly higher accuracy ratings at the medium level than at the difficult level (easy versus medium: means of 86.2 versus 65.3, t = 9.02, p< .01, medium versus difficult: means of 65.3 versus 36.27, t = 7.42, p< .01). The low-literate participants compared with high-literacy participants showed less accurate readings at all difficulty levels (easy: means of 86.2 versus 99.8, t = 3.66, p< .01; medium: means of 65.3 versus 99.4 t = 7.78, p< .01; difficult: means of 36.27 versus 93.9, t = 12.83, p< .01). Thus, H2a is supported.

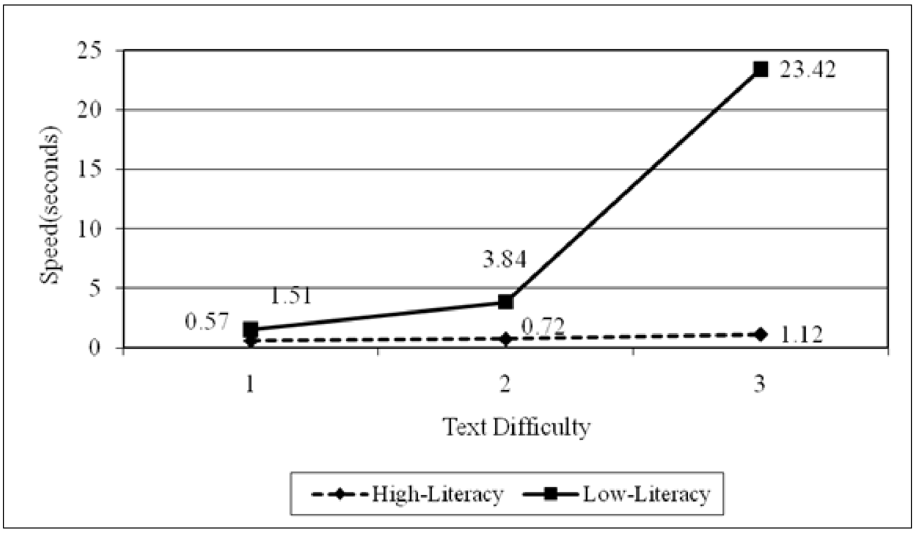

Fig 1: Interaction between literacy and text difficulty on speed

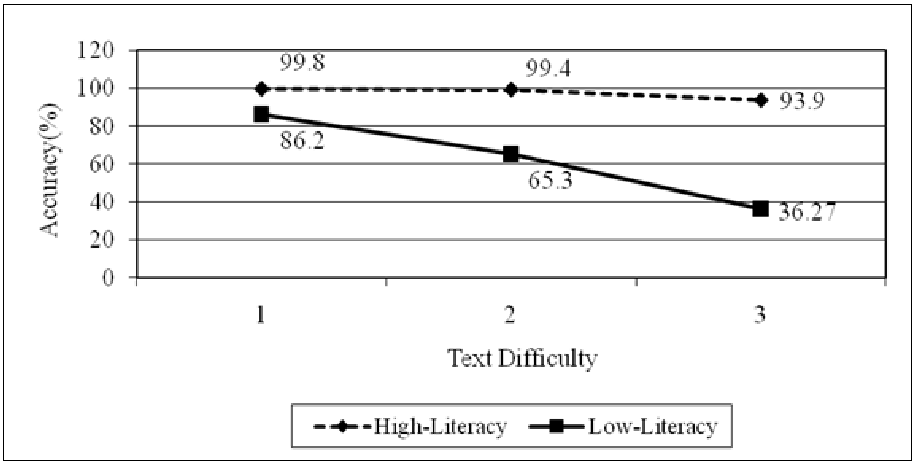

Fig 2: Interaction between literacy and text difficulty on accuracy

There was also a significant interaction between literacy and text complexity in comprehension (F (2, 72) = 3.79, *p*< .05). In support of H2b, low-literate participants' text comprehension decreased to a greater degree than high-literate participants' comprehension as the text became more difficult. Low-literate participants had significantly higher comprehension scores a) for easy text (Measy = 17.67) than for medium text (Mmedium = 12.31, t = 18.21, p< .001), and b) for medium text than for difficult text (Mdifficult = 5.21, t = 5.54, p< .001). This result indicates a 30% decrease in accuracy when going from easy to moderate text and a 57% decrease in comprehension when going from moderate to difficult text.

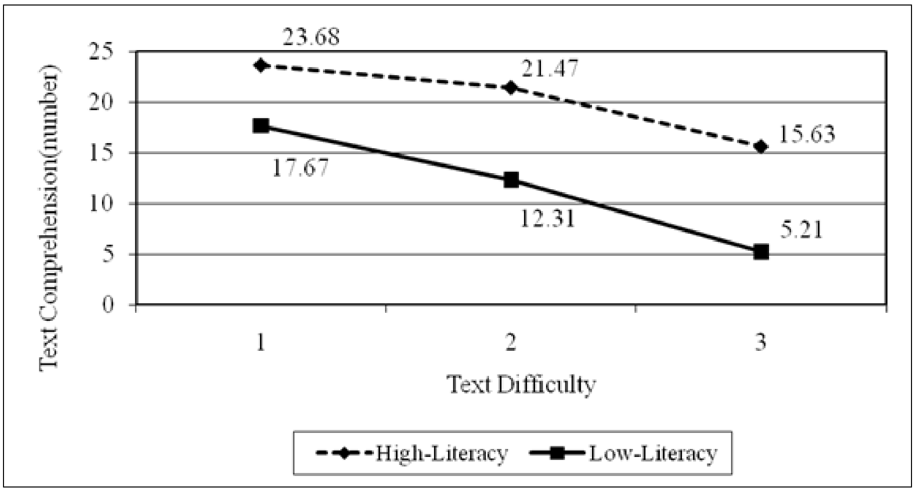

Fig 3: Interaction between literacy and text difficulty on comprehension

High-literate participants displayed a less dramatic decline in comprehension as text complexity increased. Comprehension dropped 10% between the easy and medium text (Measy = 23.68 versus Mmedium = 21.47, t = 2.03, p< .05) and 26% when going from medium to difficult text (Mmedium = 21.64 versus Mdifficult = 15.63, t = 4.87, p< .001). Thus, Hypothesis 2b is supported. High-literate participants displayed a less dramatic decline in comprehension as text complexity increased. Comprehension dropped 10% between the easy and medium text (Measy = 23.68 versus Mmedium = 21.47, t = 2.03, p< .05) and 26% when going from medium to difficult text (Mmedium = 21.64 versus Mdifficult = 15.63, t = 4.87, p< .001). Thus, Hypothesis 2b is supported.

Finally, the role of verbal working memory capacity as a mediator is examined in text comprehension. Independent samples *t*-test revealed a significant difference in the verbal working memory capacity of high- and low-literate participants as low-literate participants recalled significantly fewer last words in the listening span test (*M* low-literate = 24.57 out of 60) than high-literate participants (*M* high-literacy = 47.26, *t* = 13.53, *p*< .001). Baron and Kenny's (1986) [33] regression procedure was employed to investigate the potential mediating effect of verbal working memory capacity in the relationship between word processing and text comprehension. Three equations demonstrated full mediation.

Equation one indicates that speed was a significant predictor of text comprehension (β = -.711, *p*< .001). In the second equation, speed was a significant predictor of working memory capacity (β = -.713, *p*< .001). Finally, when working memory capacity and speed are regressed on comprehension together, working memory capacity remains a significant predictor of text comprehension (β = .814, *p*< .001) and eliminates the otherwise significant effect of speed on text comprehension (β = -.130, *p*> .15) satisfying the conditions of full mediation.

Local accuracy was a significant predictor (*p*< .01) when both text comprehension and working memory capacity were dependent variables (Equation1 and 2). There was evidence for partial mediation since the beta value of accuracy was reduced when working memory capacity was included as an independent variable (.893 versus .422). We conducted a Sobel test to investigate the mediation indirect effect (see Sobel 1982 for detailed formula) [34].

The result showed that the difference between the two coefficients for accuracy (indirect effect) predictor was significant (*t* = 3.87, *p*< .01). Thus, local text processing became a significant variable, predicting text processing as suggested by VET (1985). Thus, Hypothesis 3, and the basic premise of VET, is supported.

Table 2: Mediation Testing: Speed

	Equation 1	**Equation 2**	**Equation 3**
	Text Comprehension as Dependent Variable	**Working Memory Capacity as Dependent Variable**	**Text Comprehension as Dependent Variable**
Regression Model	P= .000	P=.000	P=.000
Speed	P=.000 (-.711*)	P=.000 (-.713)	P= .196 (-.130)
Working Memory Capacity			P=.000 (.814)

*Beta coefficient

Table 3: Mediation Testing: Accuracy

	Equation 1	Equation 2	Equation 3
	Text Comprehension as Dependent Variable	Working Memory Capacity as Dependent Variable	Text Comprehension as Dependent Variable
Regression Model	P= .000	P=. 000	P=. 000
Accuracy	P=. 000 (.893*)	P=. 000 (.877)	P= .003 (.422)
Working Memory Capacity			P=. 000 (.537)

*Beta coefficient

5. Conclusions

According to VET (Perfetti, 1985) [20], inefficient local processing is a key cause of poor text comprehension due to the reduced working memory capacity remaining after local processing. Perfetti (1985) [20] suggested that poor readers may be more inefficient at local processing and thus leave little room for working memory capacity for overall text comprehension. This study finds that low-literate participants read significantly slower than high-literate participants at the word level of reading. As the difficulty of text level increased, the discrepancy widened between low- and high-literate participants. Low-literate participants read much less accurately than high-literate participants at the word-level reading. Again, as text difficulty increased, this discrepancy widened between low- and high-literate participants. While high-literate participants maintained their accuracy rate fairly steadily, low-literate participants read the words less accurately, and accuracy dropped significantly lower as the difficulty of words increased. The results confirmed that low-literate participants tend to display inefficient local text processing because they spend more cognitive resources at the processing stage associated with lower-level reading (Daneman & Carpenter, 1980) [21].

Following VET theory, this study provides empirical evidence that low-literate adult's process text less accurately due to inefficient word-level processing than high-literate adults, with a widening discrepancy in comprehension as the text becomes more difficult. This research also emphasizes the critical role of working memory capacity as a mediator. Future studies on increasing working memory capacity for low-literate adults, such as providing graphical information to compensate for inefficient local processing, could be a fruitful research avenue.

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