The Role of Working Memory in Explaining Reading Comprehension Performance in University Students

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Abstract:

This study investigates the crucial role of working memory capacity in reading comprehension in young adults; it describes readers' working memory abilities and their reading comprehension capacities, and it examines the effect of students' working memory on their reading comprehension. To this end, two tests measuring storage abilities and reading comprehension are administered to one hundred third year English language students. Finally the calculated correlations have shown a very significant relationship between working memory and reading comprehension.

Key words: Reading comprehension, working memory, storage, information processing, correlation

ملخص:

تبحث هذه الدراسة الدور الحاسم لسعة الذاكرة العاملة في الاستيعاب القرائي لدى البالغين من الشباب. والهدف من هــذه الورقة هو وصف قدرات الذاكرة العاملة وقدرات الطلاب على الفهم في القراءة من نص مكتوب و مدى تأثير قدرات هذه الذاكرة على قدرات الطلاب على الاستيعاب القرائي. تحقيقا لهذه الغاية أجرينا اختبارين لقياس قدرات التخزين والاستيعاب القرائي لمائة طالب السنة الثالثة. وأخيرا يتم حساب الارتباطات بين المتغيرتين المذكورتين سابقا وتحليلها. النتائج بينت وجود علاقة مهمة بين الذاكرة العاملة والقراءة والفهم.

الكلمات المفتاحية: الاستيعاب القرائي، الذاكرة العاملة، التخزين ، معالجة المعلومات، الارتباطات

Introduction :

Getting meaning from the text is a hard reading task. Readers might be fluent during the reading course but do not actually understand what they are reading. To find out about what makes text understanding difficult is not an easy task since many components contribute in the process of reading (Dunlosky and Tauber, 2007). Researchers in the field of reading have been focusing, in the last 30 years, on the crucial role metacognition plays in text understanding. Yet recent years have seen relevant progress in the study of the relationship between working memory (WM) and reading comprehension, which leads to a growing recognition of the link between working memory and text understanding (Daneman and Carpenter, 1980; Baddeley, 1997). In this paper, thus, the focus is not on decoding issues or lexical access problems as text comprehension difficulties that are not higher-order comprehension problems (Oakhill and Cain, 2007). It is mainly on the current issues of reading that consider the impact of working memory capacity on the students' reading comprehension: storage and processing function of memory on which reading puts a lot of demand.

1. Review of the Literature

1.1. Reading Comprehension

Reading comprehension might seem to be a simple concept that everyone understands what it stands for; however, it is a controversial issue. Huey (1908) considers it as one of the "most intricate workings of the human mind." This idea is explained, according to the Reading Research Group (RAND), by the fact that understanding a text by building its coherent representation is a complex process one can go through while reading. Reading comprehension is, thus, a process that combines information from text with the reader's prior knowledge (Snow, 2002).

Reading comprehension notions have changed over the years. Consequently, models of text comprehension differ in many concepts. Kintsch and Van Dijk (1978), in their model, at a local or a micro level, the text is made up of ideas that take the form of propositions that consist of a predicate and an argument. Those taking the form of a predicate "may be realized in the surface structure as verbs, adjectives, adverbs, and sentence connectives" (Kintsch and Van Dijk, p.367). In this model, propositions are ranked in a hierarchy and the readers' understanding depends on their capacity to establish what they call a referential coherence (argument-proposition overlap). So while reading, readers have to relate the incoming propositions with those already existing in a short-term memory buffer through argument overlap.

Another reading comprehension model is proposed by Trabasso and his colleagues (Magliano, Trabasso and Graesser, 1999; Trabasso, Suh, Payton, and Jain, 1995; Trabasso and Magliano, 1996; Trabasso and Suh, 1993). They Assume that coherence in texts can be achieved through creating causal relations between sentences (Trabasso and Suh, 1993, p.7). To put it differently, text comprehension requires linking incoming events, actions, and outcomes to their causal antecedents, which will build causal chains at a global level. The importance of a text unit, according to this model, consists, first, of the number of the causal relationships that a unit has with other units in the very same (they will be more important and better recalled). Second, when a unit belongs to a causal chain, it will be more important and better recalled than the other units that do not belong to a causal chain (Trabasso, Suh, Payton, and Jain, 1995; Trabasso and Magliano, 1996).

It is noteworthy that in these earlier models of reading comprehension, the term working memory has not been mentioned as such; it has been replaced by the term short-term memory buffer, which is a limited-capacity buffer that has an important role in many models. However, in a later version of the model, Kintsch (1998) has found out that comprehension can take place without the presence of a short-term memory buffer. This latter can simply aid working memory by making readers form a more coherent text-base. That makes working memory the mechanism that helps readers link different text elements to build a better text coherence (Kintsch, 1998).

1.2. Working Memory

The term working memory refers to a dynamic brain system that enables human beings to store and manipulate information while engaging in complex cognitive task such as comprehension, problem solving…etc (Baddley and Hitch, 1974; Savage, Lavers, and Pillay, 2007).

Since working memory enables the simultaneous storage and processing of information, the original model of working memory divides it into three subcomponents (Baddeley, 2000). First, the central executive controls and regulates attention system and cognitive processes. This system is important because it activates long-term memory and enables human beings to move smoothly from one cognitively demanding task to another one (Baddeley, 2000). The visuospatial sketch pad is another working memory system that, as its name indicates it, manipulates and stores visual image and spatial information. The third subcomponent is the phonological loop; it maintains and rehearses speech-based input. Actually, it is crucial for vocabulary acquisition, be it in a native or a second language (Baddeley 1997).

Later, Baddeley (2000) has suggested a fourth subcomponent; the episodic buffer. This system is an intermediate factor between the two slave systems and the central executive that binds input in the form of coherent episodes (Baddeley, 2000).

The role of working memory, as supported in this model, is crucial in academic performances, namely language comprehension in children and adults (Swanson, 1993). Actually, it relates some parts of working memory to reading comprehension. Specifically, the central executive and the phonological loop (as a verbal part of working memory) help readers understand in a crucial sense; that is how a constant integration of incoming information is possible during reading (Gathercole and Baddeley, 1993). Some researchers, by the same token, have hypothesized that working memory is one of the principal determinants of reading comprehension individual differences (Baddeley, 2007; Daneman and Carpenter, 1980; Perfetti, 1985).

The present paper is a study that considers the influence of students' differences in working memory capacities and its influence on their reading achievements, namely reading comprehension. To achieve the previously specified goal, a correlation between students' reading comprehension and working memory capacities is made.

2. The Study

In this study, the belief about the importance of working memory in reading comprehension would be answered. This belief, taking the form of a prediction, is that higher working memory spans comprehend texts written in English as a foreign language better than lower spans.

2.1. Method

2.1.1. Subjects

The participants in this study make up a representative sample of 100 students drawn randomly form a population of 465 third year students learning English at the department of Letters and English Language, Faculty of letters and languages, University of Frères Mentouri-1, Constantine. It consists of 22 males (22%) and 77 females (77%). This information, nevertheless, is not taken into consideration in the analysis of the obtained results because sex a completely different variable from the variables at hand.

The reason behind choosing third years is that they are, for the majority, at the intermediate level of learning, which makes it possible to test how working memory influences their reading comprehension abilities.

2.1.2. Measures and Procedures

2.1.2.1. Reading Comprehension Measure

This measure is a modified version of the original Nelson and Denny test version. Modifications have been made to make the task less difficult in consideration of the Algerian learners who have been administered this test. It consists of twenty (20) multiple choice questions (MCQ). These questions target the different abilities a reader might need to comprehend a text. One question is more general; it raises the point about a short passage purpose. Two questions are asked later about the main idea of a short expository paragraph. Then, two questions require the students to find a logical conclusion to what has been understood in two expository paragraphs. Additionally, students are asked to guess the meaning of two words using their context, which is in this case a couple of sentences. Also, this measure considers students abilities to understand separate sentences, to understand the supporting details of the main idea, to grasp sentence relations and to read between the lines and get the hidden message or implied information.

This measure has been administered during the normal class timing. However, it did not last for a whole class; it has lasted for 45 minutes. This period of time is fair enough to read all the test sentences, paragraphs and text and answer their multiple choice questions.

2.1.2.2. Working Memory Measures

This measure consists of two subtests: Reading span task and operational span task.

2.1.2.2.1. Reading Span Task

The Reading Span task aims at assessing the participants recalling capacities using reading. This measure is a modified version of the Daneman and Carpenter (1980) original task that is difficult for non native English speakers. It consists of sixty (60) sentences that are divided into 15 sets (50 % are grammatically and semantically correct; 50 % are incorrect) and the final word of each sentence is a noun. Each set consists of three (3) sentences. The sets get longer progressively to contain at the beginning two (2), then three sentences (3) and so on until we reach to the three last sets that contain six (6). The participants read the sentences from a data show while they are being displayed. Each sentence will be displayed for 9 seconds; and at the end of each set, students are given 6 seconds to judge whether the sentences are grammatically and semantically correct, and to recall the last word of each sentence following the same order they have been displayed in.

2.1.2.2.2 Operational Span Task

The Operational span task measures the participants recalling capacities using letters and arithmetic equations. This task is a modified version of the Turner and Engle's (1989) since it is of a higher level of difficulty for the participants. This assessment tool consists of twenty two (22) questions that have been displayed using data show equipments (a five-seconds display for each question). Some of them require a mere recalling of letters in their order of display. Some other questions require the participants to solve mathematical equations. The third category is the most complicated of the three since students are shown two equations to solve and two letters to recall in the correct order in the same test item.

2.2. Data Collection and Analysis

The data obtained using the previously mentioned measures are summarized in the following tables.

Question type	Question numbers and Percentage of correct answers
Recognising text form	Q1 (30%)
Constructing main idea	Q2 (69%), Q3 (44%)
Drawing conclusions	Q4 (56%), Q5 (34%)
Guessing meaning from context	Q6 (54%), Q7 (30%)
Understanding separate sentences	Q8 (35%)
Understanding main idea support	Q9 (39%)
Understanding sentence relation	Q10 (66%), Q11 (59%), Q12 (10%), Q13 (89%)
Extracting implied information	Q14 (5%), Q15 (35%)
Recalling chronological events	Q16 (86%), Q17 (34%), Q18 (45%), Q19 (55%),Q20 (40%)

Table 01: Students Performance in the Reading Comprehension Test

The data in the previous table represent the percentage of students' correct answers in the reading comprehension test. What is noteworthy is that participants are more likely to perform well and in a larger number when questions are cognitively less demanding. This can be remarked in their answers to questions two and three where they have simply to check a paragraph's general idea. Other questions seem to be, for those participants, more demanding especially when they have to recall chronological events or understanding separate sentences like questions eight, eighteen, and nineteen. Some other questions make a good performance difficult; they are mainly about extracting implied information such as questions fourteen and fifteen. It is logical that the more demanding a task is, the lower students' performances are.

Sentence sets	Set numbers and average percentage of correct answers
2-sentence sets	Set 1 (98%), Set 2(89.25%), Set 3(88.5%)
3-sentence sets	Set 1 (82.33%), Set 2(66.5%), Set 3(70.5%)
4-sentence sets	Set 1 (58.75%), Set 2(54.12%), Set 3(46.5%)
5-sentence sets	Set 1 (56.4%), Set 2(45.8%), Set 3(42.7%)
6-sentence sets	Set 1 (43%), Set 2(42%), Set 3(42.25%)

Table 02: Students' Performance in the Reading Span Test

The previous tables summarises the percentage of the students' performance in the reading span test. As expected, the students can remember the last word in each set's sentence mainly when there are less words to remember like the earlier sets in this task. Moving through longer sets, students find it more difficult to recall all the ending words in their exact order, especially that they have to make a grammatical and semantic judgment of the sentences beforehand. Performing two tasks at the same time is not easily controlled by the study's participants. In some cases, their failure might be due the fact that the words to be recalled are just unfamiliar to them.

Question numbers	Q1-7	Q8-12	Q13-17	Q18-19	Q20	Q21	Q22
Percentage of correct answers	100%	70%	50%	20%	10%	5%	0%

Table 03: students' Performance in the Operational Span Task

Table 03 represents the percentage of students' correct answers in the 22 operational span task. Considering the participants answers, it is noticeable that earlier items in the task are easier for the students since they have to recall 2 letters at once (items 1, 2 and 3). Additionally, questions four to 18 have shown to be less easy since students have to calculate and check an equation mentally in five seconds. The further they move, the more difficult it gets and the less performing they become. The category of questions 19, 20, 21 and 22 have a higher level of difficulty since students are interrupted by an arithmetic equation while trying to recall a letter. This has shown to be, expectedly, the most challenging part of the task.

2.3. Results and Discussion

To examine the nature of the relationship between working memory capacities and reading comprehension abilities, the correlation coefficient 'r' is a required. This coefficient expresses the degree of correspondence between working memory and reading comprehension scores (Paler-Calmorin and Calmorin, 2006). Hopefully, this correlation shows that the increases in the magnitude of working memory will lead to increases in the reading comprehension one.

Since the nature of the relationship between the two variables in question is linear, then the Pearson product-moment correlation (PPMC) is the most appropriate one to be used. The equation for this correlation coefficient 'r' is:

$$r(xy) = \frac{\Sigma \text{ xy}}{(N)(SDx)(SDy)}$$

-The value of 'r' ranges from "-1" (to indicate a perfect negative correlation) to "+1" (to indicate a perfect positive correlation).

In this study, 'x' represents participants' working memory scores (global or component ones), 'y' represents reading comprehension ones, SDx is the standard deviation of 'x' scores, SDy is the standard deviation of 'y' scores, and N refers to the number of cases.

-General Correlation between Reading Comprehension and Working Memory

To calculate this correlation, the previous equation symbols are replaced by their real values that are the students' scores in working memory and reading comprehension measures. After the computation of Pearson product-moment correlation coefficient 'r' between working memory and reading comprehension, and since, with this one-tailed test, we predict a positive correlation between working memory and reading comprehension, at 0.05 level of significance, with 98 degrees of freedom, the critical value of 'r' is 0.165, and the value of 'r' obtained is 0.81, the results are statistically very significant and are well in the direction of our hypothesis.

The following scatter graph represents the results obtained.

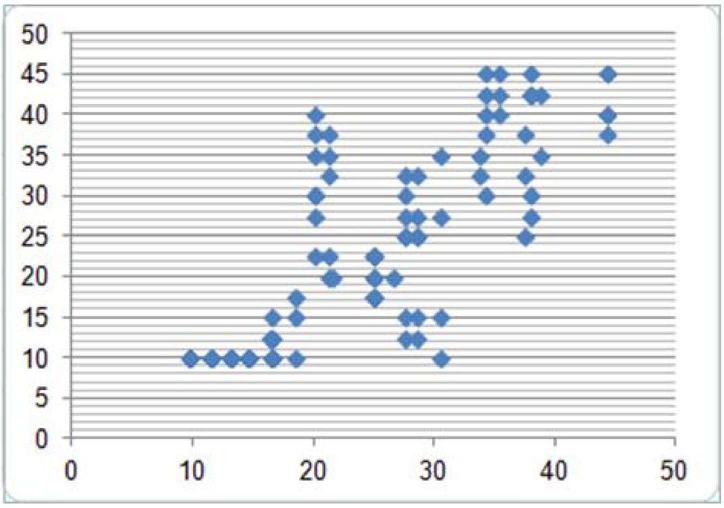

Figure 01: Correlation between Working Memory and Reading Comprehension

Each point in the previous graph represents the crossing point of each participant's scores. The horizontal axis represents working memory scores and the vertical one represents the reading comprehension ones. The distribution of these points indicates the strong positive correlation between working memory and reading comprehension, since it shows that most participants occupy the same position in both variables (high working memory capacity→ high reading Comprehension ability, low working memory capacity→ low reading comprehension ablity). However, it is noteworthy that some points are separated from the diagonal group; they represent some exceptions that correlated unexpectedly and, thus, do not go in the direction of the study's expectations.

The results obtained confirm, once again, that working memory capacities explain reading comprehension abilities in young adults. It is a limited capacity processing resource that has proved its relevance in reading comprehension (Daneman and Carpenter, 1980). This study supports the point that the reader needs higher working memory capacities to be able to receive, maintain and manipulate information (selection of relevant information and suppression of irrelevant one) while constructing a mental representation of the text beforehand (Gernsbacher et al., 1990).

Conclusion

This paper provides evidence about the nature of the relationship between reading comprehension and working memory. It has revealed, in line with the study's expectations, that to be a good, skilled text comprehender, the reader must form a coherent mental representation of the text while manipulating information. This means that his working memory must execute different cognitive processes while reading. Therefore, the study's significant results permit the prediction of students' reading comprehension abilities from knowledge about their working memory capacity.

References

1-Baddeley, A. D. (1997). Human memory: theory and practice. Boston: Allyn &Bacon.
2-Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? Trends in Cognitive Science, 4, 417-423.
3-Baddeley A. D. (2007). Working memory, thought and action. Oxford, England: Oxford University Press.
4-Baddeley, A. D., and Hitch, G. (1974). Working memory. Psychology of Learning and Motivation, 8, 47–90.
5-Daneman, M., and Carpenter, P. A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behaviour, 19, 450-466.
6-Dunlosky, J., Serra, M., and Baker, J.M.C. (2007). Metamemory. In F. Durso, R. Nickerson, S., Dumais, S. Lewandowsky, and T. Perfect (Eds.), Handbook of applied cognition (2nd Ed., pp.137-159). New York: Wiley
7-Gathercole, S. E., and Baddeley, A. D. (1993). Working Memory and language. Hillsdale, NJ: Erlbaum.
8-Gernsbacher, M. A., Varner, K. R., and Faust, M. E. (1990). Investigating differences in general comprehension skill. Journal of Experimental Psychology: Learning, Memory and Cognition,16, 430-445.
9-Huey, E. B. (1908). The psychology and pedagogy of reading. London: Macmillan.
10-Kintsch, W. (1998). Comprehension: A paradigm for cognition. Cambridge: Cambridge University Press.
11-Kintsch, W., and van Dijk, T. A. (1978). Toward a model of text comprehension and production. Psychological Review, 85 (5), 363-94.
12-Magliano, J. P., Trabasso, T. and Graesser, A. C. (1999). Strategic processing during comprehension. Journal of Educational Psychology, 91 (4), 615-629.
13-Oakhill, J.; and Cain, K. (2007). Introduction to comprehension development. In K. Kate and J. Oakhill (Eds.). Reading comprehension strategies: Theories, interventions and technologies (pp. 47-71). New York: The Guilford Press.
14-Paler-Calmorin, L., and Calmorin, M.A. (2006). Statistics in education and the sciences. Philippines: Rex Bookstore.
15-Perfetti, C. (1985). Reading ability. New York: Oxford University Press.
16-Savage, R., Lavers, N., and Pillay, V. (2007). Working memory and reading difficulties: What we know and what we don't know about the relationship. Educational Psychological Review, 19, 185-221.
17-Trabasso, T. and Magliano, J. P. (1996). Conscious understanding during comprehension. Discourse Process, 21 (3), 255-287.
18-Trabasso, T. and Suh, S. (1993). Understanding text: achieving explanatory coherence through on-line inferences and mental operations in working memory. Discourse Processes, 16 (1-2), 3-34.
19-Trabasso, T., Suh, S., Payton, P., and Jain, R. (1995). Explanatory inferences and other strategies during comprehension and their effect on recall. In R. F. Lorch & E. J. O'Brien (Eds.), Sources of coherence in reading (p.p. 219-239). Hillsdale, NJ: Lawrence Erlbaum Associates.
20-Snow, C. (2002). Reading for understanding: toward an R&D program in reading comprehension. Santa Monica, CA: RAND.
21-Swanson, H. L. (1993). Working memory in learning disability subgroups. Journal of Experimental Child Psychology, 56, 87-114.
22-Turner, M. and Engle, R. (1989). Is working memory capacity task dependent? Journal of Memory and Language, 28, 127-54.