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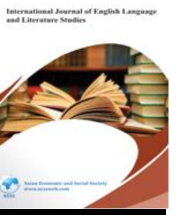

THE ROLES OF WORKING MEMORY COMPONENTS IN VOCABULARY KNOWLEDGE

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ABSTRACT

This study investigated the relationship between working memory components and receptive and productive vocabulary knowledge. The letter span and backward digit span tasks were used as verbal and nonverbal measures of working memory storage component respectively. The verbal and nonverbal executive control components were measured by the reading span and operation span tasks separately. Measures of receptive and productive vocabulary were frequency-based tests. The results suggested that the executive control component plays a more prominent role in vocabulary knowledge (both receptive and productive) compared to the storage component. In addition, the correlation between working memory components and productive vocabulary was stronger than their correlation with receptive vocabulary. The highest correlation was found between the verbal executive control component and productive vocabulary while the lowest one was identified between the nonverbal storage component and receptive vocabulary. The results highlight how each working memory component plays a role in retrieving vocabulary knowledge.

Keywords: Storage component, Executive control component, Receptive vocabulary, Productive vocabulary.

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Contribution/ Originality: This study is one of very few studies that investigated the relationship between WM components and vocabulary knowledge by taking into account the distinction between receptive and productive aspects of vocabulary knowledge.

1. INTRODUCTION

Foreign language comprehension and production is difficult for EFL learners due to the demands it places on working memory (WM). Working memory is defined as the human cognitive

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system responsible for temporary processing and storage of information with limited capacity (Baddeley, 1997;2003). Baddeley (1986) argues that WM can be divided into the storage component which temporarily stores information and the executive control component that is responsible for both storage and processing of information. The executive control component selects to attend or to reject incoming information (Baddeley, 1996), retrieves information from long term memory, reflects on that information, and manipulates it when necessary (Baddeley, 2000).

For measuring WM components, a variety of tasks has been proposed and used. A classification of tasks is mentioned by Linck *et al.* (2013): simple span tasks measure individual's ability to store information (the storage component) and complex span tasks measure individual's ability to store and process information simultaneously (the executive control component). They further classified WM measures based on the content domain of the stimuli into verbal (requiring processing of linguistic material) and nonverbal (requiring processing of nonlinguistic material). Based on this classification, word span, non-word span, and letter span tasks measure the verbal storage component. Digit span, counting span, backward digit span, letter rotation, and size judgment tasks measure the nonverbal storage component. On the other hand, reading span, listening span, speaking span, and English opposites span tasks are considered as measures of the verbal executive control component and operation span, math span, N-back, and AMIPB are used as measures of the nonverbal executive control component.

The role of WM in language acquisition has been studied extensively. It has been suggested that the ability to learn a foreign language is related to WM and numerous studies have investigated the relationship between WM and different language skills and sub-skills. For instance, Kormos and Sáfár (2008) argue that individuals with higher WM capacity outperform those with lower memory capacity in different aspects of second language learning and performance. In a longitudinal study, Cain *et al.* (2004) investigate the relationship between WM and reading comprehension in children between 8 to 11 years old and confirm this relation. This result is consistent with Harrington and Sawyer (1992) findings who examine the relationship between advanced L2 learners' WM capacity and reading skill. In another study conducted by Leeser (2007), it is concluded that WM capacity plays some role in learners' L2 reading comprehension and processing grammatical forms. With respect to grammatical rule learning, Williams and Lovatt (2003) also find correlation between phonological memory ability (the phonological component of WM) and rule learning.

The relationship between WM capacity and listening comprehension was also investigated. Wayland *et al.* (2013) investigate the impact of several factors including passage length, information density, and WM on listening comprehension. They posit that listeners' WM capacity predicts performance in listening comprehension tasks.

In the area of speaking skill, Fortkamp (1999) explores whether WM would be a good predictor of L2 speech fluency. The result indicates a significant correlation between WM capacity and L2 speech rate. Fortkamp (2000) expands the previous study by adding accuracy, complexity, and weighted lexical density to the variables under investigation. The result suggests that individuals with higher WM capacity tend to be more fluent, accurate, and complex in L2 speech production. Olive (2003) addresses the role of WM in writing and reveals the relationship between each component of WM and various writing processes. A similar study was carried out by Bergsleithner (2010) to account for whether individual differences in WM capacity can be related to L2 writing performance. She concludes that there is a significant relationship between WM capacity and L2 writing performance.

Regarding the relationship between verbal WM capacity and vocabulary knowledge, Gathercole *et al.* (1999) mention that the association between phonological memory and vocabulary knowledge is strong among both teenagers and younger children. Moreover, in a study conducted by Hu (2003) about the role of phonological memory and phonological awareness in foreign language word learning, it has been found that phonological memory may support FL vocabulary learning. Martin and Ellis (2012) also analyzed the relationship between phonological short-term memory (PSTM) and WM, and vocabulary and grammar learning. The result reveals strong associations.

Considering the above-mentioned studies, it can be said that in investigating the relationship between WM capacity and vocabulary knowledge, the distinction between receptive and productive aspects of vocabulary knowledge and their relations with different components of WM have not been addressed sufficiently. Therefore, the present study focused on the relationship between verbal and nonverbal WM storage and executive control components and receptive/productive vocabulary knowledge.

2. METHOD

2.1. Participants

Participants of this study were female adults between 23 and 29 years old who wanted to attend a teacher-training course with the aim of teaching English to Iranian children under the age of twelve. Since having IELTS score of at least 6 was one of the prerequisites to attend the course, homogeneity of the group was checked based on their IELTS scores. Totally, 56 participants from three teacher-training courses attended this study.

Because attention was a key factor in this study, one of WM measures which is called the operation Span task was first taken by the participants. The participants whose math scores of the operation span test were below 17 were excluded from the study due to inadequate attention to the test. This criterion for administrating memory span tasks was recommended by Bender (2005b) in his instruction for taking operation span tasks. As a result, 9 participants were excluded and the study was carried out with 47 participants

2.2. Instruments

For data collection, four measures of WM and two measures of vocabulary knowledge were used. Based on Linck *et al.'s* (2013) classification, the letter span task was used as the verbal measure of WM storage component and its nonverbal counterpart was the backward digit span task. Both these tasks are called simple tasks. The reading span task was used as the verbal measure of WM executive control component and the operation span task was its nonverbal counterpart. These tasks are both complex tasks.

2.2.1. Letter Span (LS)

In this test, uppercase consonant letters appeared on the computer screen one after another and each for one second. Totally, 14 sets of letters appeared and each set consisted of 2 to 8 letters. The participants were required to read them aloud, remember them at the end of each set, and write them in order. If a letter was forgotten, a blank had to be left on the answer sheet. Each participant's score was the number of letters from each list that had been correctly written in order. The highest score in this test was 70. The same test was used in other studies such as Martens and Johnson (2009)

2.2.2. Backward Digit Span (BDS)

The digit span task was used in studies such as Gathercole *et al.* (1999), Palladino and Cornoldi (2004), and Kaushanskaya *et al.* (2011). For this study, the backward digit span designed by Bender (2005a) was used. The participants were required to recall a string of digits in reverse order immediately after presentation. Totally, 14 lists of digits were presented. The number of digits in each list increased from 2 to 8 as the trial progressed. The digits were presented at a rate of 1 digit per second. After each list, the participants were asked to recall the digits in reverse order. If a digit was forgotten, a blank had to be left on the answer sheet. The number of digits from each list that was completed correctly was the participant's score. The total score could be as high as 70.

2.2.3. Reading Span (RS)

Our RS test was based on Daneman and Carpenter's (1980) reading span task. The participants were asked to read aloud sets of two to six sentences and attempt to remember the last word of each sentence. The participants started with the easiest trials that included two sentences and continued to the most difficult ones with six sentences. The sentences had 13–16 words and they were presented from smallest to largest. The task terminated when each participant failed a majority of the trials in a level. Scoring the RS task can be done in a variety of ways. However, in a study carried out by Friedman and Miyake (2005), it was found that among methods of scoring the RS test, two methods of *the total number of words recalled* and *the proportion of words per set averaged across all sets*-which are more normally distributed- have higher reliability, and have higher correlations with criterion measures such as reading comprehension. Based on the results of their study, for scoring procedure, the method of total number of words was used. It means that a participant's score was the total number of words recalled across all trials. For instance, if a participant remembered four out of five words on a trial, his/her score for that trial was four. In our study, the maximum possible score was the total number of sentences in the reading span test that was 40.

2.2.4. Operation Span (OS)

According to Conway *et al.* (2005), the operation span is a reliable and valid measure of working memory. This task requires students to solve a series of math operations while attempting to remember a set of words. For data collection, the OS test designed by Bender (2005b) was used. It included 20 items that formed five lists of 2 to 6 operation-word strings. Each string was a short math operation and a word that appeared for about 5 seconds on the computer screen. In 5 seconds, the participants were required to decide about the correctness of the operations and write Y for correct and N for wrong operations on their answer sheet. After judging the operations, they had to say the words aloud to themselves. At the end of each list, the participants were directed to write the words in order on their answer sheets. They had to leave blank spaces for the words they had forgotten. After writing, the next list was presented. At the end of administration, the operation part and the word part were scored separately. For the math part, each correct item was awarded one point. Therefore, the total point was 20. If the math score was 17 or higher, the participants' word memory score was considered a relatively valid assessment of their WM. The participants whose operation scores were below 17 were excluded from the study due to inadequate attention to the test. For scoring word lists, according to Conway *et al.* (2005), we awarded one point for each full list that was remembered correctly. Partial points were awarded to the lists that were partly recalled. It means that the number of words recalled was divided by the number of words for that list. At the end, all the points were added up and divided by 5. As the test included 5 lists, the final score could range from 0.00 to 1.00.

2.2.5. Productive Vocabulary Test

Laufer and Nation's (1999) frequency based test was used as the measure of productive vocabulary. For taking this test, the participants had to fill in the blanks of some sentences with suitable words.

2.2.6. Receptive Vocabulary Test

Schmitt *et al.'s* (2001) frequency based test was employed as the measure of receptive vocabulary. This test was in the form of matching items with their dictionary definitions. The words were presented in groups of six or seven with three or four definitions in front of them.

2.3. Procedure

Before administrating the WM tasks, they were piloted with a group of 6 participants who were homogeneous with the participants of the study based on their IELTS score to detect any problem regarding the participants' understanding of the test taking procedure, unclear instructions, and items of the tasks. After the pilot study, the participants of the main study were instructed how to do the tasks and they had an opportunity to practice a short trial.

For data collection procedure, one simple and one complex memory task, namely the letter span and the operation span, were administered before vocabulary tests and the next two simple and complex tasks, namely the backward digit span and the reading span, were carried out by the participants after the vocabulary tests. The productive vocabulary test was also administered before the receptive one. The reason was to prevent the participants from remembering the words of the productive test based on the receptive test's options. This procedure was based on De la Fuente's (2002) idea for taking productive and receptive vocabulary tests.

It is worth mentioning that the first WM test taken by the participants was operation span. According to Bender's (2005b) instruction, the participants with math scores below 17 were excluded from the study due to inadequate attention to the test. The participants who remained in the study underwent the rest of the tests.

3. RESULTS

This study employed Pearson Correlation to probe any relationship between the variables. The correlations between working memory components and productive vocabulary are presented in Table 1.

Table-1. Correlations between productive vocabulary and RS, OS, LS, and BDS

		RS	OS	LS	BDS
Productive Vocabulary	Pearson Correlation	.702**	.696**	.686**	.651**
	Sig.(2-tailed)	.000	.000	.000	.000
	N	47	47	47	47

**p<.01

Based on Table 1, it can be said that there was a significant relationship between the participants' verbal working memory executive control component (measured by the RS) and their productive vocabulary knowledge ($R (45) = .702, P < .01$). Significant correlations were also found between the participants' nonverbal working memory executive control component (measured by OS) and their productive vocabulary knowledge ($R (45) = .696, P < .01$), the participants' verbal working memory storage component (measured by LS) and their productive vocabulary knowledge ($R (45) = .686, P < .01$), and the participants' nonverbal working memory storage component (measured by BDS) and their productive vocabulary knowledge ($R (45) = .651, P < .01$). Moreover, the strongest correlation can be seen between the verbal working memory executive control component and productive vocabulary (.702) and the poorest one was found between the nonverbal working memory storage component and productive vocabulary knowledge (.651).

Table 2 highlights correlations between working memory components and receptive vocabulary.

Table-2. Correlations between receptive vocabulary and RS, OS, LS, and BDS

		RS	OS	LS	BDS
Receptive Vocabulary	Pearson Correlation	.562**	.540**	.531**	.493**
	Sig.(2-tailed)	.000	.000	.000	.000
	N	47	47	47	47

**p<.01

Regarding Table 2, it is apparent that the relationship between the participants' verbal working memory executive control component (measured by RS) and their receptive vocabulary knowledge (R (45) = .562, P < .01) is significant. There was also a significant relationship between the participants' nonverbal working memory executive control component (measured by OS) and their receptive vocabulary knowledge (R (45) = .540, P < .01), the participants' verbal working memory storage component (measured by LS) and their receptive vocabulary knowledge (R (45) = .531, P < .01), and the participants' nonverbal working memory storage component (measured by BDS) and their receptive vocabulary knowledge (R (45) = .493, P < .01). In addition, in this table, the highest correlation can be found between verbal working memory executive control component and receptive vocabulary (.562) and the lowest one is the relationship between nonverbal working memory storage component and receptive vocabulary knowledge (.493).

4. DISCUSSION

This study was carried out to probe any relationship between verbal/nonverbal WM executive control as well as storage components and vocabulary knowledge. The results suggested that, first; generally, the relationship between verbal and nonverbal WM executive control and storage components and vocabulary knowledge (receptive and productive) is significant. Second, the relationship between WM executive control component and vocabulary knowledge (both receptive and productive) is stronger than the relationship between WM storage component and vocabulary knowledge (receptive and productive). Third, the correlation is stronger between WM executive control and storage components and productive vocabulary compared to the relationship between WM executive control and storage components and receptive vocabulary. Fourth, the strongest correlation was found between verbal WM executive control component and productive vocabulary. Fifth, the lowest correlation was identified between nonverbal WM storage component and receptive vocabulary.

The results lend further support to the previous studies that advocate the relationship between WM capacity and vocabulary knowledge. It is worth mentioning that while previous studies (Gathercole *et al.*, 1999; Haughey, 2002; Hu, 2003; Martin and Ellis, 2012) put emphasis on the relationship between verbal WM and vocabulary knowledge, our results indicated that nonverbal WM also plays a part in and is related to vocabulary knowledge.

More specifically, our results are congruent with Linck *et al.* (2013) findings which suggested that the executive control component of WM is more strongly related to L2 outcomes rather than the storage component. Although Linck et al. considered learners' L2 proficiency and did not focus their attention on vocabulary knowledge, based on our findings, it can be said that their result is generalizable to vocabulary knowledge as a subset of L2 proficiency. This finding supports the fact that vocabulary knowledge can be better accounted for based on the links between the storage component, long-term WM, and the mediating role of the executive control component mentioned by Baddeley and Hitch (1974). Consistent with Linck *et al.* (2013) findings, role of the executive control component may be more important than simply keeping information in the storage component.

This result is also consolidated by the findings of our research that indicated the stronger correlation between WM executive control and storage components and productive vocabulary compared to the correlation between these components and receptive vocabulary. As productive vocabulary knowledge is a more complex structure than receptive vocabulary knowledge (Laufer, 1998; Lee, 2003), this finding demonstrates more powerful links and transmission of information between storage component, long-term WM, and executive control component which retrieve a word for the purpose of production.

Our next finding, which revealed the strongest correlation between verbal executive control component and productive vocabulary knowledge, is consistent with Gathercole *et al.* (1999), Hu (2003), Haughey (2002), and Martin and Ellis (2012) results which put emphasis on a strong relationship between verbal WM and vocabulary knowledge. However, our findings add more details to the previous ones by differentiating between WM components and suggesting that this relation is strong between verbal aspects of the executive control component and productive vocabulary. This result also fits with Speciale *et al.* (2004) findings who argued that while phonological sequence learning predicts receptive vocabulary learning, phonological sequence learning and verbal WM capacity make independent contributions to productive vocabulary learning. It seems that productive vocabulary relies on the role played by verbal WM for word retrieval. However, considering correlations between different measures of WM and productive vocabulary, it can be seen that this relation is stronger for OS (nonverbal) than for LS (verbal). It may indicate that although the relation between verbal WM and productive vocabulary knowledge is strong, it is limited to executive control component not the storage one.

Lastly, the lowest correlation between nonverbal storage component and receptive vocabulary may demonstrate the reliance of receptive vocabulary on nonverbal aspects of words such as their written shapes and also less demand it puts on executive control component for processing information.

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