Vocabulary recall and retention improvement: Working memory training using dual N-back task

Seyed Mojtaba Marashi[*], Islamic Azad University, Department of Persian Literature and Foreign Languages, Tehran, Iran

Mina Adibi Sadinezhad, Islamic Azad University, Department of Persian Literature and Foreign Languages, Tehran, Iran

Abstract

Working memory (WM) plays an important role in learning since it serves as the buffer between past sensations and future behaviour, making it essential to understand not only how we encode and recall sensory information in memory but also how we plan for its upcoming use. This study examined the effect of WM training on vocabulary recall and retention of Iranian EFL learners using the dual n-back task technique. N-back requires the individual to remember an item that was presented a certain number of items previously. To this end, 50 EFL learners were randomly assigned to the experimental (*n* = 25) and control (*n* = 25) groups. The participants were taught 100 English words in 20 sessions. In each session, the experimental group also received a dual n-back task. The obtained data were analysed through two-way repeated measures analysis of variance and independent samples *t*-tests. The results showed that the experimental group outperformed the control group in target words' recall and retention.

Keywords: Dual n-back task, EFL learners, working memory training, vocabulary recall, vocabulary retention

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[*] ADDRESS FOR CORRESPONDENCE: Seyed Mojtaba Marashi, Islamic Azad University, Department of Persian Literature and Foreign Languages, Tehran, Iran
E-mail address: ames9000@gmail.com

1. Introduction

Memory is an ambiguous term. It always implies some relationship in time, some connection between a present impression and a past event (Fellman et al., 2020; Holmes et al., 2019). Very probably this distinction between past and present is consciously recognised only by man. The mechanism by which we recall the past is frequently a process of matching a present image with a past image. This matching can be a conscious examination of several possibilities. The successful matching of a present image with a past image involves a process of recognition. Memory, which is the process by which we acquire knowledge of the world and modify our subsequent behaviour, is essential for learning (Dehn, 2011; Goo et al., 2015; Janacsek & Nemeth, 2015; Spada & Tomita, 2010; Van Abswoude et al., 2020). It has been suggested that working memory (WM) supports language learning (Baddeley, 2003, 2012; Peng & Swanson, 2022; Wen et al., 2019). WM is important for many activities both in first and second language acquisition (Heidari, 2020). According to Baddeley (2003, p. 189), WM refers to the 'temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive activities'.

Researchers have examined the role of WM in various L2 language processes, including reading (Joh & Plakans, 2017; Walter et al., 2006), writing (Adams & Guillot, 2008; Mavrou, 2020), sentence processing (Felser & Roberts, 2007; Juffs, 2004), speaking (Kondo, 2021), vocabulary development (Ansarin & Khabbazi, 2021), learning grammar (Suzuki, 2019; Williams & Lovatt, 2005) and the processing of input and intake (Indrarathne & Kormos, 2018; Mackey et al., 2010). WM has also been implicated as a core element in L2 aptitude (Dörnyei & Skehan, 2003; Grymska, 2016) and as a predictor of overall proficiency (Oka et al., 2021; Vallejos, 2020; Van Den Noort et al., 2008).

The dominant theory of WM is the multicomponent Baddeley and Hitch model which was promulgated in 1974 and later revised by Baddeley (2003, 2006). This model defines WM as 'a limited capacity temporary storage system that underpins complex human thought' (Baddeley, 2007, p. 7). Over the years, Baddeley has described several core central executive functions, including (a) focusing attention on relevant information while inhibiting the irrelevant information; (b) switching between concurrent cognitive activities; (c) applying strategies, such as conscious rehearsal; (d) allocating limited resources to other parts of the WM system; and (e) retrieving, holding, and manipulating temporarily activated information from LTM.

According to the LTM model, WM is a system with several different parts that control the information being processed (Forsberg et al., 2021; Sepp et al., 2019). This led to the development of Baddeley's Model of WM. This model assumes that each component has a limited capacity and is relative, not entirely, independent of the others. Baddeley's original model contained three components, the phonological loop, the visuospatial sketchpad, and the central executive. However, the current model also contains the episodic buffer. In contrast, performance decrements when two tasks are combined indicate that they share a reliance on the same component. This empirical approach has proved invaluable in fractionating WM into its constituent parts, leading to the most recent version of the WM model, advanced by Baddeley (2000) (Figure 1).
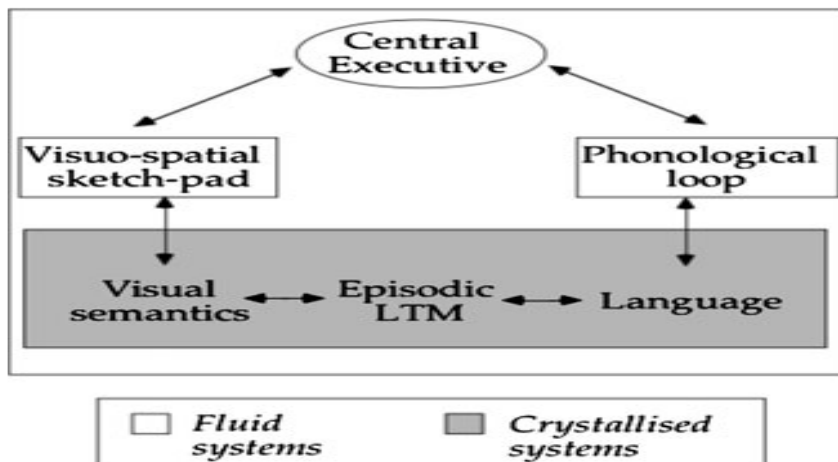
Figure 1

Multi-Component WM Model. Source: Adapted from Baddeley (2012, p. 11)

1.1. Purpose of study

The concept of a phonological loop has not gone unchallenged, however. To date, the theoretical underpinnings of the phonological loop continue to be researched and have produced interesting developments in our understanding of language acquisition and processing (Baddeley, 2007). In this study, we examined the effect of WM training through using dual n-back tasks on vocabulary recall and retention of Iranian EFL learners.

1.2. Conceptual background

A widely used means of measuring WM is the n-back task. The dual n-back task is a variation of memory assessment that was proposed by Jaeggi et al. (2008). In the dual-task paradigm, two independent sequences are presented simultaneously, typically using different modalities of stimuli, such as one auditory and one visual. In the n-back task, the participant is shown a series of items (e.g., letters, words, or location markers) and is asked to decide, upon presentation of each item, whether a given property of the current item matches the same property of the item N presentations back. Variations in n can be used to assess individuals' levels of processing capacity or to set a level of dual-task competition. Since its inception, the n-back task has been brought to bear on a host of issues related to WM.

Nearly all cognitive and metacognitive functions are closely interrelated with WM (Martin et al., 2021). For example, language expression, processing speed, reasoning, phonological processing, attentional control, and executive functions have high correlations with WM. Furthermore, nearly all aspects of learning, especially academic learning, depend on adequate levels of WM Finally, performance and application of skills, as well as cognitively challenging daily activities, depend on WM. WM has been assumed to involve two different systems of maintenance, a phonological loop, and a central attentional system. Though the capacity estimate for letters of each of these systems is about 4, the maximum number of letters that individuals can immediately recall, a measure known as simple span, is not about 8 but 6. One of the most known problems among second language learners is memorising the meaning of vocabulary while still wanting to recall it when needed.

Some researchers have shown that WM might predict the overall understanding of EFL learners. For EFL learners' reading comprehension, background knowledge, language skill, processing, and analysis of the information (i.e., vocabulary) are related to each other processes related to WM (Gathercole, 2007). A sufficient measure of examination has been directed on L2 vocabulary obtaining and additionally on WM limit. Notwithstanding, more studies are required to research the conceivable relationship between WM limit and L2 vocabulary recall/retention. In response to this call, the study described in this article drew on a pretest-treatment–posttest-experimental-design to explore whether WM capacity training helps the extent to which L2 learners benefit from using dual n-back task training for partially-acquired L2 vocabulary.

EFL students with higher WM capacity do better in school than students with lower WM capacity. Successful acquisition of academic skills and the performance of those skills rely heavily on WM. All things considered, it needs more investigation and examination to discover a linkage between the purported variables throughout the current research. Since Second language researchers and L2 instructional method look to address the topic of why a few learners struggle to procure an L2 (as a rule in educated settings), specialists have been keen on seeing if WM constraints clarify contrasts in achievement in an assortment of spaces. The reason for choosing this subgroup of English vocabulary was that, despite their high frequency and importance, they are particularly difficult for non-native speakers to learn, even at advanced levels of proficiency (Mitchell, 2018).

1.3. Review of the literature

The studies on vocabulary can be divided into two broad types: those examining vocabulary size as the outcome variable (predictive research) and those investigating treatment effects on learning rate (experimental research). Within each category, the research can be further divided according to whether the predictor variable is phonological short-term memory (PSTM) or executive WM. PSTM is a predictor of vocabulary size, and the finding was obtained for both adults (Hummel, 2009) and young children (Farnia & Geva, 2011; Gathercole & Masoura, 2005). Executive WM, however, is a weak and unstable predictor of vocabulary size (D'Angiulli et al., 2001; Engel de Abreu & Gathercole, 2012; Jean & Geva, 2009).

Experimental studies typically include one or more treatment sessions where learners were engaged in so-called 'paired-associate' tasks in which learners were presented with L2 words and their first language (L1) translations. This research shows that PSTM was important for learning new vocabulary at the initial stages of learning (Atkins & Baddeley, 1998; Martin & Ellis, 2012; Speciale et al., 2004). However, at more advanced stages, where learners had an extensive learning experience, PSTM stopped being a significant predictor, and previous vocabulary knowledge emerged as a more important factor (French & O'Brien, 2008; Ghazanfar & Farvardin, 2015; Verhagen & Leseman, 2016). Executive WM was also found to be predictive of learning rate in studies where learners had no background in the target language (Juffs & Harrington, 2011; Kempe et al., 2010; Perez, 2020), but because of the lack of relevant research, it remains unknown whether it is less predictive of vocabulary learning at more advanced stages of learning – as has been found for PSTM.

2. Materials and method

Along with the previous studies in the field of WM and to extend the scope of its expansion, this study aimed to apply dual n-back task training by using memory workshop software, alongside teaching new vocabulary, to Iranian EFL learners.

2.1. Participants

The participants were selected from 100 university students holding Bachelor of Arts degrees in different majors at Islamic Azad University, Shoushtar Branch. The participants' first language was Farsi. The participants were male and female, aged between 25 to 40 years old. For the study, the Vocabulary Size Test (Schmitt's vocabulary size test 2001) including 2000, 3000, 5000, and 10000 level tests were applied as the pre-test. Each level included 30 items and the amount of 20 minutes for each level of proficiency was considered for participants. After gathering test scores, and according to existing facilities, among the remaining population, 50 participants were selected. The participants were then divided randomly into two groups, experimental and control groups. Each group consisted of 25 participants.

2.2. Data collection instrument

To obtain measurable data with which the results of the current study could be statically analysed, the following instruments were utilised

2.2.1. Schmitt's vocabulary size test (2000)

It is designed to measure both first-language and second-language learners' written receptive vocabulary size in English. The test measures largely decontextualised knowledge of the word although the tested word appears in a single non-defining context in the test.

2.2.2. Dual n-back task

The n-back task has been found to involve several executive functions that have been linked to the relationship between WM and fluid intelligence, including the processes of attentional control, updating, and the inhibition of interference. It enables subjects to improve their WM capacity and fluid intelligence. The dual n-back task involves remembering a sequence of spoken letters and a sequence of positions of a square at the same time and identifying. It includes recalling stimuli or their location without any need to process the information, deal with distractors, or manipulate images are classified as visual-spatial STM measures. All cognitive and memory subtests measure multiple cognitive and memory abilities. This is not due only to the structure, content, and demands of the subtests themselves. Rather, it mainly reflects the integrated functioning of the brain.

2.2.3. Vocabulary test

A vocabulary test consisting of 20 matching vocabulary items based on the follow-up activities of each session was given (newly taught vocabulary). It was to demonstrate the lexical improvement of participants in the pre-test and post-test phases and to determine to what extent using the Dual n-back task in teaching was effective.

2.3. Procedure

Before treatment sessions, the Vocabulary Levels Tests were conducted among 100 participants. Among 120 items, 70 items with the maximum wrong answers that most of the participants did not respond them, were selected. After excluding the highest and lowest scores, 64 subjects remained. Of these, 50 participants were selected randomly based on drawing numbers out of a hat. Then they were assigned into two groups, the control, and the experimental group. While the control group received conventional teaching, the experimental group worked with Dual-N Back software at the end of each treatment session. For testing the validity of the selected items for use in the treatment sessions, 60

words from the tests and 10 words from external materials were selected and used in a pilot study. The study was carried out during a vocabulary retention/recall measuring course consisting of 12 sessions spread over about 1 month, 3 days a week, each session 75 minutes. Finally, after 3 weeks' intervals between the post-test and final vocabulary test, both experimental and control groups took a test namely a delayed test. Again, it was a vocabulary-level test with slight modifications in the arrangement.

2.4. Ethical consideration

There are no conflicts of interest in this study. During and after the research, all participants remained anonymous, and the study poses no harm to society.

3. Results

The results of the research revealed the effectiveness of using dual n-back task training and WM capacity development and it is significant and learners benefit from using the task during their study period. Also, the findings showed that the dual n-back task plays a crucial role in expanding WM of Iranian EFL learners' vocabulary recall and retention.

Table 1 presents the descriptive statistics for the control and experimental group over time.

Table 1
Descriptive Statistics for the Control Group and the Experimental Group Over Time

Group		Time 1 (Pretest)		Time 2 (Im. Posttest)		Time 3 (Del. Posttest)	
		M	SD	*M*	SD	*M*	SD
	N						
Experimental	25	29.88	7.52	50.88	8.64	47.48	8.02
Control	25	29.84	7.03	35.56	6.36	30.68	5.41

As can be seen in Table 1, the mean of the pretest in the experimental group is 29.88 and, in the posttest, increased to 50.88 and in the delayed posttest it was 47.48, while in the control group, the mean score in the pretest is 29.84, and it changes to 35.56 in posttest and finally it decreased to 30.68 in delayed posttest. The standard deviation in the experimental group was 7.52, 8.64, and 8.02 in the pretest, posttest, and delayed posttest respectively. Also, the standard deviation has changed in the pretest, posttest, and delayed posttests by 7.03, 6.36, and 5.41 respectively.

To find out the effect of treatment between the control and experimental group over time, we have run two-way repeated measures analysis of variance (ANOVA). The results are shown in Table 2 below:

Table 2
Two-Way Repeated Measures ANOVA

Source	df	*F*	*p*
Between subjects			

Group	1	1,222.76	<0.01
Within subjects			
Time	2	296.16	<0.01
Time × group	2	134.30	<0.01

As Table 2 showed variance between the subjects' group mean (*F* value) is equal to 1,222.76 and the *p*-value is 0.01. On the other hand, the variance within subjects during test administration times is equal to 296.16, and the time by a group is 134.30.

Table 3 shows the result of independent samples *t*-tests for posttests:

Table 3
Independent Samples T-Tests for Posttests

Posttest		*f*	
Time 2- after 1 week	0.14	8	0.01
Time 3- after 3 weeks	0.68	8	0.01

As can be seen in Table 3, the *t* score after 1 week of treatment is 7.14 and after 3 weeks is 8.68. The *p*-value observed and degree of freedom are 0.01 and 48 for both respectively.

Finally, the Bonferroni pairwise comparisons have been implied. It can be used to correct any set of *p* values for multiple comparisons and is not restricted to use as a follow-up test to ANOVA.

Table 4
Bonferroni Pairwise Comparisons for the Experimental Group

Time (I)	Time (J)	Gain (Mean difference)	Sig.
Time 1	Time 2	−21	0.00
Time 2	Time 3	3.40	0.00
Time 1	Time 3	−17.60	0.00

As Table 4 shows the comparison between the results of time 1 and time 2 shows −21 in mean difference and it is 3.40 in comparison of time 2 and time 3 results and finally in comparison of time 1 and time 3 mean changes to −17.60. The level of significance was 0.00 for all test results.

4. Discussion

In this study dual n-back task was used as a treatment to see whether this kind of training has any effect. Vocabulary acquisition was assessed by an immediate posttest, where individuals attempted to recall words and attempted to answer the questions from Schmitts' vocabulary size test, which were the same

as the pretest with some modifications. In this test, the participants had to find the correct definition among three available definitions. The mean score of the experimental group in the pretest was 29.88 compared to 50.88 in the posttest and the control group, it was 29.84 in the pretest and 35.56 in the posttest. It indicates improvements in the result of the experimental group over the control group. The results suggested that the application of WM training in the experimental group had an impact on their actual performance (post-test), resulting in a smaller gap between the recall of the vocabulary and WM capacity expansion.

Regarding the short-term effect, the experiment group showed a higher mean score in the immediate post-test than the control group while there was not any significant difference in the two groups' pre-test. The findings of the current experimental study provided empirical support for the effectiveness of applying dual n-back tasks on vocabulary retention of Iranian EFL learners. The difference between the results of the pretest, posttest, and delayed posttest (mean score) revealed that using dual n-back task training affected significantly the learners' vocabulary retention over a long period.

Taking research outcomes into account based on the statistical analysis of results of various calculations such as Bonferroni pairwise comparisons, two-way repeated measure ANOVA, and independent sample *t*-test of three phases of this study including pre-test, post-test, and delayed post-test demonstrated that there were significant differences between the results of pre-test and post-test and delayed posttest of vocabulary retention in the experimental group. WM and long-term memory have reciprocal influences on each other that are difficult to separate. The relationship is bidirectional: Long-term knowledge is used to recall and enhance short-term and WM representations, and WM facilitates the building and retrieval of long-term structures.

The findings showed that the dual n-back task plays a crucial role in expanding WM of Iranian EFL learners' vocabulary recall and retention. The above-mentioned results of this study are in line with various findings in different language learning domains. Following Alloway (2013), the development of WM capacity in the recall and retention phases was significant. Also, the results of this study are in line with L2 reading comprehension studies, such as Adams and Shahnazari-Dorcheh (2013). The difference between the results of the pretest, posttest, and delayed posttest (mean score) revealed that using dual n-back task training affected significantly the learners' vocabulary retention over a long period. Finally, the findings support the results of a study conducted by Jaeggi et al. (2014) and Au et al. (2015) that indicates a significant correlation between using dual n-back tasks and memory expansion.

Finally, as a finding of this study, the experimental group which used dual n-back task training improved their retention and ability to recall information more exactly and even after a long period. Participants given dual n-back task training performed better than those who were given no treatment. The findings contribute to the idea that L2 vocabulary memorisation and use over long periods can be achieved by using software like dual n-back task training and other software as a medium to improve WM capacity. This result indicates that although both the experimental and control group developed their scores, the experimental group that received Dual n-back task training outperformed. Also, it can be said that the WM training had a positive effect on short-term memory for vocabulary recall in the experimental group when compared to the control group who did not receive the training.

The findings of the current experimental study provided empirical support for the effectiveness of using dual n-back task training on vocabulary recall and retention among Iranian EFL learners. The obvious effect of the usefulness of using dual n-back task training might be attributed to the fact that all participants in the experimental group who were exposed to using dual n-back tasks after each session, performed better than the other group. They were exposed to the use of dual n-back task training after

each session for 15 minutes. The data collected showed that exposure to using dual n-back task training has a significant effect on participants in experimental group recall and retention. Therefore, according to the findings, the participants could also expand their memory by using dual n-back task training. Individuals' WM capacity, presents a significant correlation with vocabulary acquisition in an L2 situation. This statement justifies why the great majority of the participants claimed they had learned most of the words taught during the period of data collection.

It is noteworthy that some words are more difficult to learn due to their feature of being abstract, thus being less prone to being visualised and to being transferred to long-term memory. Knowing the relationships between EFL vocabulary knowledge and WM functions is valuable information that can guide assessment, interpretation of results, and diagnosis of learning disorders. Students with different WM capacities tend to demonstrate unique types of remedies in educational settings. Thus, an individual's WM profile, at least to some extent, can help to differentiate among the types of remedies that must be used.

5. Conclusion

The results indicate that WM performance can reliably differentiate between students with high and those who are slow learners. Although recently activated LTM items contribute to WM capacity and function, there are currently no standardised instruments for assessing the number of such items and the speed with which they can be accessed. Nonetheless, the extent to which LTM is supporting WM functioning should be considered and assessed informally.

N-back is very effective because it challenges executive WM by requiring continual updating, switching, and inhibiting. The only concern with n-back is that it is too challenging for younger children, especially those less than 8 years of age. For adults and those who handle n-back well, the task can be made more challenging by creating a dual n-back, such as having to remember both auditory and visual information about an item presented n-items before.

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