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The effect of verbal and visuospatial working memory spans on collocation processing in learners of English*

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Abstract
Much interest has recently been directed toward the knowledge of collocations in the field of second language learning since they have been asserted to improve fluency. The current study was intended to examine the effect of verbal and visuospatial working memory spans on the processing of collocations using a Self-Pace Reading Task (SPRT) and relevant working memory tasks. To this end, participants were divided into two distinct groups (high vs. low) based on their scores in the verbal and visuospatial memory tasks. The results of the analyses revealed that there was not a statistically significant difference between high and low verbal memory groups in the processing of collocations. However, a significant difference was witnessed between high and low visuospatial memory groups in their reaction time. These results have important implications for the multi-word processing models and the way collocations should be taught in the classroom.

Key words: Verbal Working Memory (VWM), Visuo-Spatial Working Memory (VSWM), restricted collocations, retrieval speed (of collocations), self-paced reading

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Introduction

Language learning is a complex process which shares a lot with many disciplines such as psychology, neurology, sociology of language, and some others. Psychology of language as one of the aforementioned fields of study which is technically named psycholinguistics deals with complex psychological processes performed in the mind such as comprehension and production of language, be it the first or second language.

The interaction between language and other general cognitive systems has recently attracted a lot of attention such as different types of memory systems. Working Memory (WM) as one of the types has been proclaimed as "perhaps the most significant achievement of human mental evolution" (Goldman-Rakic, 1992). It is itself considered as a multi-component model which is divided into four components: a phonological loop which is a temporary verbal or phonological storage system (also named verbal/acoustic); a visuospatial sketchpad, a storage system for form and location of objects; a central executive, a limited-capacity attentional system (Baddeley & Hitch, 1974); and a recently added component named the episodic buffer (Baddeley, 2000).

Efficiently communicating in a language such as English requires not just utilizing grammar rules and vocabulary items but formulaic language such as collocations as well. Due to the prefabricated state of collocations, these constructions which also compose a considerable portion of everyday language incur a lower processing load, promote natural language use, and improve language fluency (Wray, 2002). Also, due to working with ready-made sets of words, the learners' task is easier (Chon & Shin, 2013).

Collocation

The origin of the word collocation goes back to the 17th century when for the first time Francis Bacon used it in his book titled 'Natural History'. However, at that time he did not use it as a linguistic term and it was about a century later when in 1750 it was used as a linguistic term referring to the linear gathering of words (Palmer, 1933). Of noteworthy is the point that it was not used in a way that is reminiscent of its present day use until in the 1930s, it was defined as "units of words that are more than single words" (Ibid, p. 4). This very definition is closer to the more recent uses such as that of Oxford Collocations Dictionary (2002) that is: "the way words combine in a language to produce natural sounding speech and writing" (Deuter & Lea, 2002, p. vii).

Approaches to the study of collocations

There are heterogeneous definitions of the word collocation. Nonetheless, it has traditionally been investigated through two main viewpoints each concentrating on specific characteristics of collocations (Barfield & Gyllstad, 2009). In the first one which is known as frequency-based approach, it is the frequency or statistics of collocations which has gained attention (Halliday, 1966; Sinclair, Jones, & Daley, 2003). In other words, frequency perspective is taken to examine collocations within this first approach. Computational Linguistics and Corpus Linguistics are some of the fields whose proponents are predominantly adopting the approach.

In the 1940s, research on collocation in Russia led to the birth of a second approach to the study of collocations named phraseological approach (Cowie, 1998). Cowie (1981) mostly categorizes word combinations into two groups: 'formulae' and 'composites'. The first category is a sentence-length unit which usually has pragmatic functions while the latter unit is from a level lower than a sentence level.

Collocations, as Cowie (1981) believes, are of the composite type and are of such units "which permit the substitutability of items for at least one of its constituent elements (the sense of the other element, or elements, remaining constant)" (p. 224). The example he makes is the phrase 'run a business' in which the last component (i.e. business) could be replaced with many words such as a theater or a company.

Cowie (1994) believes collocations are transparent and in most cases lexically variable but they also have some other characteristics such as arbitrary limitations of choice. 'Cut one's throat', 'slash one's wrist', '*slash one's throat', and '? cut one's wrist' are some of the examples that he uses to exemplify his point. Furthermore, he puts forward another sub-class named 'restricted collocations'. It seems that the term comes from Aisenstadt (1979) and is defined as "word-combinations in which one element (usually the verb) [has] a technical sense, or a long-established figurative sense which [has] lost most of its analogical force" (Cowie, 1991, p. 102).

Cowie further tries to clarify the term (i.e. restricted collocation) and mentions its salient characteristics. In verb + object noun combinations, some semantic properties could be attributed to the verb. Either it has a long-established figurative sense such as 'reach an agreement' or is of a delexical type such as take, put, give, have, etc. He also proposes a criterion named substitutability, that is, this specific type of collocations – to a more extent – limits the number of lexical items appropriate to substitute for the original one(s). This rule applies to both components (i.e. verb and object noun) meaning that there are few words to substitute for the words while retaining the meaning as a restricted collocation. This last aspect of substitutability – sometimes called commutability – is so significant a factor in the phraseological approach that can distinguish it from the other types of collocations.

Types of collocations

According to Howarth (1996), there are two types of collocations named grammatical composites and lexical composites which are classified using the word class of the constituent words. In the first category belonging to grammatical composites, combinations such as preposition + noun, and adjective + preposition compose the collocation and for the other type, nouns, verbs, adjectives and adverbs in different combinations are the constituent components of the (lexical) collocations.

Working memory

In cognitive psychology, WM is referred to that part of memory in which besides preserving task-relevant information, a cognitive task is performed on information (Baddeley & Hitch, 1974; Daneman & Carpenter, 1980). In other words, WM which is also a capacity-limited part of the human cognition, as well as briefly storing information like STM, manipulates information so as to organize it with the pre-existing knowledge and delivers it to the Long-Term Memory (LTM) or might disregard it and subsequently allows it to be removed from memory (Baddeley, 2007).

To put it another way, WM helps to temporarily store information in STM and process it to become more stable in LTM or be expunged instead. What is significant regarding WM is not the storing part but the other side which concerns its processing ability and applying it to complex cognitive tasks such as reasoning, comprehension, and certain types of learning (Baddeley, 1992). That means it is the functional role WM plays in complex cognition which has given it a high-profile.

Components

Having performed some experiments on participants and requiring them to perform reasoning, comprehension, and learning tasks simultaneously, Baddeley and Hitch (1974) had come to the conclusion that they should revise the modal model of memory to a multi-component one. Thus, pondering over WM, they claimed it has three components: an attentional control, assisted by two other subsystems named visuospatial sketch pad and phonological loop (Baddeley, Gathercole, & Papagno, 1998) which are visual storage and processing and its acoustic/verbal counterpart, respectively. Although previously it had three components, a fourth component has recently been proposed by Baddeley (2000) and has been named episodic buffer.

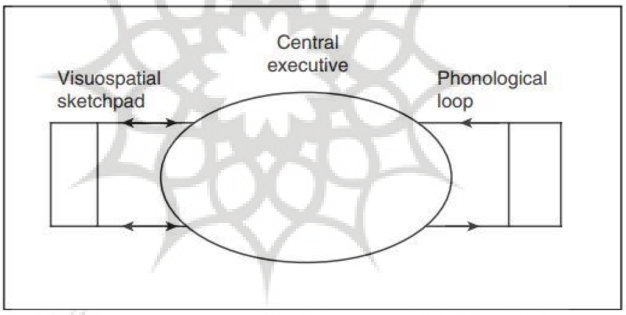

Figure 2.1 First model on working memory components.
Reprinted from *Working Memory*
, by Baddeley and Hitch,1974 , New York, NY: Mackerlin Press.

Central executive

Central executive (also named attentional control) is the most significant component of WM in that it controls attention and warrants resources to be correctly directed and properly utilized to attain the goals they have been set for. It has neither storage capacity nor interface ability (to link WM to LTM). It only focuses, divides, and switches attention between the other resources. It is this component of the model which controls attention so as to retrieve long-term knowledge and/or to integrate information from different subsystems of WM (i.e. the loop and the sketchpad) especially when there are effortful and attention-demanding processes (Allen, Baddeley, & Hitch, 2006).

Episodic buffer: a new component to the 1974 model

This new component is an almost recent addition to the Baddeley and Hitch model (1974) and could be considered as the greatest change to the model (Baddeley, 2000). This entirely new component is usually depicted as a multimodal temporary store. That means it does not hold information in a single modality such as visual or spatial or auditory or kinesthetic but it can handle all these modalities at the same time.

Baddeley (2007) defines the buffer as: "…a temporary storage system that is able to combine information from the loop, the sketchpad, long-term memory, or indeed from perceptual input, into a coherent episode." (p. 148)

The reason for the revision of the original model was that there was no link between WM and LTM and also the way separate modalities could be integrated together had not been specified. This buffer provides us with the aforementioned link and in this way it helps us draw back our previous knowledge (from LTM) during the ongoing memory and processing tasks. This link could be considered as the key theoretical breakthrough to the original version of the 1974 model.

To sum up, episodic buffer performs the following roles: 1. Linking WM to LTM so as to retrieve information from LTM into WM; 2. backing up the two slave systems by offering an extra storage mechanism; and 3. Binding and integrating information in LTM.

Phonological loop

Phonological loop, a component of WM, is specified as a slave system in a way that it only temporarily stores information and takes a passive role in manipulating it. That means it applies nothing to the information except for keeping it until central executive does the manipulation. Phonological loop is a storage buffer to remember small bits of heard information over a matter of seconds (Baddeley & Hitch, 1974).

To prevent any misunderstanding, it is needed to explain that some terminologies have changed during time and working memory (WM) is by no means an exception. One of such changes is using terms phonemic buffer/loop (Baddeley & Hitch, 1974) and the articulatory loop (Baddeley, 1986) to refer to the phonological loop component of WM (Baddeley, 1992). Due to storing heard information in this component, it is also called verbal and/or acoustic WM (Baddeley, 2003).

Also, using the term Phonological Short-Term Memory (PSTM) is another change in terminology which is usually interchangeably applied for phonological loop component of WM (e.g. Bishop, 2006; Kormos & Safar, 2008; Masoura & Gathercole, 1999; Papagno & Vallar, 1992). It seems necessary to disambiguate readers of the point that PSTM is so commonly used that most articles investigating WM components adopt PSTM other than Phonological WM. Furthermore, when retention of small bits of verbal information over a brief interval is intended for performance on specific types of task, the term phonological or verbal STM is used accordingly (Skrzypek & Singleton, 2014).

Visuospatial sketchpad

The third and last component of Baddeley and Hitch model of 1974 is visuospatial sketchpad. Exactly the same as phonological loop, this one is also a slave and passive repository of information meaning that it is not in any way clever (Baddeley, 1986). In other words, it just holds visual and spatial information over short periods of time until at a proper time, the information is called up during thinking, remembering, and processing tasks (Logie, 1995). Therefore, supporting visuospatial short-term memory (VSSTM) is the responsibility of this component of WM. As the name implies, the visuospatial sketchpad stores two kinds of information: One is visual and related to the form of objects and the other is spatial and linked to their location.

Due to fewer number of studies on VSSTM in comparison to PSTM, to better depict VSWM, Baddeley (2007) has in his recent writing expanded the role of the sketchpad claiming: "The sketchpad is a subsystem that has evolved to provide a way of integrating visuospatial information from multiple sources, visual, tactile and kinesthetic, as well as from both episodic and semantic long-term memory." (p. 101).

So far, a larger body of research on the interaction between WM and language components has only attended to Verbal Working Memory

(VWM) (e.g. Ellis, 1996; Ellis & Sinclair, 1996). vocabulary as one of the components of language has received the lion's share in this regard (e.g. Gathercole, Willis, Emslie, & Baddeley, 1992; Skrzypek, 2009). However, when it comes to Visuospatial Working Memory (VSWM), there is a dearth of research on how it can interact with language components specifically multi-word chunks such as collocations which have a direct relation with processing models. Recently, there have been calls to do more research on VSWM and how it interacts with other cognitive functions (Lilienthal, Hale, & Myerson, 2014; Rowe, Hasher, & Turcotte, 2008).

Regarding collocations, it can be claimed that in one of the approaches to their study, phraseological approach, semantic properties of collocations is heeded to (Cowie, 1981; Gitsaki, 1999). It is within this second approach that impacts of VSWM could be searched for since it could be maintained that semantic non-transparency of a word in a restricted collocation, which is the required condition for this type of collocations, might result in stimulating an imaginary state or a mental image in mind in which visualization might be activated (Gyselinck, De Beni, Pazzaglia, Meneghetti, & Mondoloni, 2007).

This imagination could possibly interact with the VSWM of a language learner, the component of WM which to a great extent has been neglected in discussions relating to the collocations. This may be considered as the foundation to start searching for any probable impact of VSWM on collocations.

Hence, the study aimed at seeking answers to the following questions:

1. Is there any significant difference between individuals with high VWM span and those with low VWM span in the processing of restricted collocations?
2. Is there any significant difference between individuals with high VSWM span and those with low VSWM span in the processing of restricted collocations?

Literature review

Most of studies on PSTM have attributed it to vocabulary in child L1 (Gathercole et al., 1992; Jarrold, Cowan, Hewes, & Riby, 2004) and L2 learning (French, 2004). Additionally, it has been found to be beneficial to adult L2 learning (Skrzypek, 2009) as well. In general, it seems that it is in the early stages of language acquisition that the relationship between PSTM and both vocabulary and grammar is at the highest state (e.g. Gathercole, Service, Hitch, Adams, & Martin, 1999; Jarrold et al., 2004; O 'brien et al., 2006).

Accordingly, the more proficient a child becomes in his/her L1, the less link is observed between vocabulary and PSTM (Costanza Papagno, Valentine, & Baddeley, 1991). Nonetheless, in adult L2 learners, PSTM and subsequent vocabulary learning are highly correlated but merely for a relatively early stages of L2 proficiency (i.e. elementary) and a little more advanced level (i.e. pre-intermediate), and not for the more advanced levels (Skrzypek, 2009).

This has provoked researchers to think of PSTM as a rudimentary language learning device for the early stages of L2 learning. In support of the claim, O 'brien et al. (2006) assert that PSTM facilitates vocabulary learning at initial stages of L2 learning but in a short time, at a relatively automatic vocabulary access level, PSTM assists L2 learners in learning more complex structures. It is, therefore, advocated that both vocabulary and grammar are generally limited by individuals' PSTM (Ellis, 1996).

In a study on formulaic language, Jiang & Nekrasova (2007) conducted a study on native and non-native English learners. They found out that both natives and non-natives had processed formulaic language faster than non-formulaic language but with few errors for the non-natives.

Considering collocations as "an important component of fluent linguistic production" (p. 4), Hyland (2008) asserts that such multi-word expressions continuously pose problems for L2 learners and have largely been neglected in Second language acquisition (SLA) research (Nesselhauf, 2003). More importantly, these prefabricated structures (i.e. collocations) are in fact quite pervasive (Sinclair, 2004) and it has been indicated that so as to effectively communicate in an L2, they are vital to a language learner (Palmer, 1933).

Collocation has become the focus of many studies such as the one conducted by Shokouhi and Mirsalari (2010) in which collocation knowledge was checked against general linguistic knowledge among Iranian EFL learners. Nonetheless, they could find no correlation between the two types of knowledge meaning that the two types of knowledge do not necessarily progress at the same rate.

In a study examining frequency effects on the comprehension of collocations, Jiang and Nekrasova (2007) reported faster processing for Korean learners of English. To test if the faster RTs are due to language proficiency, Siyanova-chanturia, Conklin, and Heuven (2011) searched for the possible effect of proficiency on high frequency collocations and noticed a processing advantage among highly proficient non-native learners for formulaic sequences over non-formulaic sequences while this was not the case with the low-proficiency non-native group. Nevertheless, no frequency effects were detected in processing lexical bundles by Valsecchi, Saage, White, and Gegenfurtner (2008). Accordingly, Han (2015) underscored that frequency along with speakers' proficiency plays the most significant role in processing.

Other than becoming fluent in an L2, collocations can improve retention of newly learned vocabulary items in the long-run. Ghezelseflou and Seyedrezaei (2015), for instance, conducted a study on the difference between retention quality of vocabulary items learned through collocations and those learned through traditional methods. The collected data indicated that words are retained for longer periods of time when learned through association with other words (i.e. in collocations).

Moreover, there seems to be few studies regarding the link between collocations and phonological STM. One of such studies is the one conducted by Bonk (2000) who states that "… [Elementary and intermediate L2 learners] may not have sufficient available processing capacity to pay careful attention to how words are conventionally combined" and if they are not certain of a correct L2 form, they use avoidance strategy or transfer it from their L1 to their L2. This resulted in proposing a hypothesis claiming that L1 transfer is more noticeable among learners with lower phonological STM than those with higher ones.

Most of this research has been on collocations in general and little attention has been directed toward specific types of collocations such as restricted collocations. With reference to the gaps in previously discussed research, as stated in the research questions, this study looks at a specific type of collocations (i.e. restricted collocations) and searches for any probable effect high or low VWM and VSWM spans on the reaction times latencies to comprehend such word co-occurrences.

Methodology

Participants:

A total of 84 MA and PhD non-English major students willingly enrolled to participate in the research out of which only 43 participants could reach the cut-off score in the Quick OPT. To have more promising results, the data attained from two participants who scored beyond ± 2 SD in OPT or backward digit span or Corsi Block-tapping task and also two left-handed participants were excluded from all analyses, resulting in a final sample of 39 participants.

Data from all 39 participants were included in the second research question regarding the VSWM span groups; while only 26 of them could take part in the first research question (i.e. VWM span groups) and the rest were excluded due to their grouping process which will soon be explained.

The mean of participants' age for the VSWM phase of the study was 25.54 (SD: 2.25 and age range: 32-23 = 9) and except for two of the participants, the rest were all males (94.87 percent). The mean of participants' age range for the VWM phase was 24.8 (SD: 2.63 and age range: 32 - 23 =9) and except for one of the participants, the rest were all males (95.15 percent).

Instruments*:*

There were four instruments used for data collection purposes in this study including:

1. A quick OPT which was composed of 60 multiple-choice questions. It has been designed by Oxford University Press and University of

Cambridge Local Examinations Syndicate and was downloaded from *http://www.ccdnat.unimi.it/files/esempio_quickplacementtest-pen-paper6.pdf*

2. A computerized backward digit span task to gauge VWM span, downloaded from website *http://www.millisecond.com/download/library/DigitSpan/* and subsequently adapted to remove the first part (i.e. forward digit span) which was not needed for the current research.
3. A computerized Corsi Block-tapping task to measure VSWM span, adopted from website *http://www.millisecond.com/download/library/CorsiBlockTappingTask/*
4. A specifically designed Self-Paced Reading Task (SPRT) of collocations relevant to the purpose of the research which was run on DMDX (version 5.1.3004) designed by University of Arizona.

Procedure*:*

In order to better clarify the procedures, this section has to be explained in two parts: item development and testing sessions. In the first part, how the collocations have been chosen for the research purpose is in enough detail explained and in the second part, timing, locations, and testing sessions are expounded.

Item development:

The collocations needed for the research were of a type named restricted collocations but as it seems there is no book or corpus to have categorized them in this specific class. Therefore, these collocations had to be somehow subjectively found and selected according to their definition.

However, these constructions do not appear to be very frequent and had to be selected so meticulously that most upper-intermediate ESL learners be familiar with. Accordingly, the last resort to find such collocations was using a corpus (COCA in this case) to first detect the most frequent words and then check their collocations in a dictionary such as OXFORD or Longman Dictionary Of Contemporary English (LDOCE).

To this end, 5000 most frequent words were downloaded from <u>*http://www.wordfrequency.info/free.asp*</u> which has been attained from Corpus Of Contemporary American English (COCA). Then, the most frequent adjectives, nouns, and verbs were found and subsequently checked in collocation section of each word in LDOCE. The following pictures are to clarify the explanations:

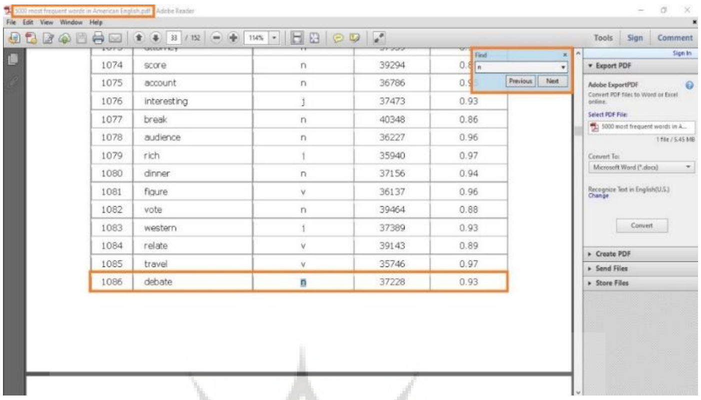

Figure 3.1 A snapshot of the PDF document adopted from <u>*http://www.wordfrequency.info/free.asp*</u>

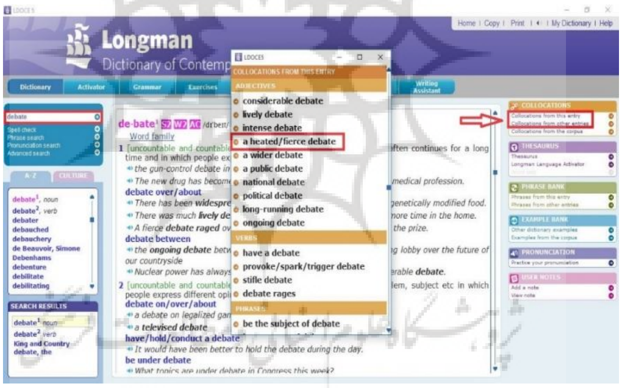

Figure 3.2 A snapshot of the Longman Dictionary Of Contemporary English (LDOCE)

In so doing, 65 bi- and trigram (i.e. two- and three-constituent) restricted collocations were found. All these collocations were first checked in Oxford Dictionary Of Idioms (2nd edition) to ascertain none of them is an idiom. Furthermore, a familiarity scale list composed of 5 point Likert-scale items was designed for all collocations (n=65) and piloted among 27 upper-intermediate language learners in one of language institutes in Urmia, West Azerbayjan, Iran. Having piloted the familiarity scale list, the researcher had to omit some collocations (with familiarity scale < 3), leading to a list containing 40 restricted collocations (25 bigrams and 15 trigrams). Four other collocations of the list were later on detected to be idioms and deleted subsequently. Consequently, there were 36 (lexical) collocations in the final list (23 bigrams and 13 trigrams).

Instead of checking the frequency of collocations which is to somehow ascertain about the familiarity of participants based on native speaker criteria, the collocations were piloted in EFL context to better check their familiarity within the context of examination. Also, checking congruency of collocations which is a very important factor was not possible since the participants were from different language backgrounds such as Persian, Kurdish, and Azeri.

Of noteworthy is the point that due to determining restricted collocations based on semantic property and the opacity nature of their components, a usually significant factor for checking collocability of sets of co-occurring words called Mutual Information (MI) was not considered. MI is usually considered when the method of inspecting collocations is a frequency-based approach and not when the approach used is a phraseology-based one which gives utmost significance to semantic property (and not frequency) as it is the case with the study.

Testing sessions:

The whole data was gathered from three sessions. Both of memory experiments were run on a laptop. Thus, any possibility of experimenter effects had been eliminated. Each session is briefly discussed in this section.

Quick OPT

The test itself had been designed by Oxford University Press and University of Cambridge Local Examinations Syndicate. The test had to be answered in 40 minutes and consisted of 60 questions out of which 25 questions concerned five short cloze tests. Due to the great number of participants, it was not possible to give the test to all the participants at the same location simultaneously.

Participants (n=84) were divided into four groups and tested on four different sessions. Two of the sessions were held at the language laboratory of Faculty of Humanities at TMU and the other two sessions were held at the study of one of TMU's dormitories with the almost greatest number of students. Both locations almost enjoyed the same testing conditions such as lighting, temperature, and noise. The questions were in multiple choice format and participants were required to check the answers on an answer sheet. Refreshments were also given after the test session.

Verbal and Visuo-spatial working memory (VWM & VSWM)

The second session was devoted to the WM tests. Previously piloting tests on 5 students other than the sample group, the longest time to complete VWM and VSWM were estimated to be 8 min and 7 min, respectively. For the sake of ethics of research, prior to the start of the session, approximate time for each test was announced to the participants. Since the two tests had to be given in one session, to nullify any probable effect of one on the other, they were counterbalanced. Refreshments were again available after the test session.

Self-Paced Reading Task (SPRT)

Participants were required to take the SPRT within DMDX on the researcher's laptop. The task started with an instruction on how to go through phrases and comprehension checks using spacebar and shift keys, respectively. Before the real experiment, there were of course a practice session containing six sentences and five comprehension checks to further familiarize the participants with the procedure on how to go on with the rest in real experiment. Practice session records were not included in the analysis.

At the end of the practice session, there was a reminder of the required keys and the instruction on how to use them. In addition, prior to starting the experiment, they had been informed that in case of having any questions, they can feel free to ask. Refreshments were also distributed after this last test session.

Results

Totally, there were two data structures: one was composed of 39 participants (37 males and 2 females) for the VSWM groups and the other had 26 participants (25 males and 1 female). There were 36 collocations altogether out of which 23 were bigrams and 13 were trigrams.

There existed 1404 observations (39 × 36) for the VSWM participants and 936 observations (26 × 36) for the VWM participants. These latencies were the dependent variable which had to be checked later on against high and low VWM/VSWM spans. However, there was one score for each participant which was his/ her mean RT on all the 36 collocations. There were no records of missing values and the extreme values (i.e. outliers) were removed in later stages of the analysis.

Number of participants in each of the high and low VWM span groups was as it has been shown in the following tables.

VWM groups

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	12	46.2	43.2	46.2
	High	14	53.8	53.8	100.0
	Total	26	100.0	100.0	

Table 4.1 Frequency data of the VWM groups

In order to have two groups of almost equal sizes for the VWM spans among all 39 participants, the midpoint score, which was 7, was subsequently excluded from all the analyses (13 participants were removed this way). The other two groups each included scores for three VWM span sizes; that is, 4, 5, and 6 were labeled as low group and 8, 9, and 10 labeled as high group. In this way, there were 12 participants in the low group and 14 ones in the high group.

Similarly, the same procedure was applied to the VSWM spans; however, to have an almost equal number of scores in each group, it was not needed to exclude any VSWM span scores for categorizing the participants into groups. As the Table 4. Shows, there were 20 participants in low group and 19 participants in high group.

VSWM groups

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	20	51.3	51.3	51.3
	High	19	48.7	48.7	100.0
	Total	39	100.0	100.0	

Table 4.2 Frequency data of the VSWM groups

Next, it was time to specify the most appropriate tests for the statistical analysis of the data. First, to choose among the available tests of comparing two groups, it was required to determine whether parametric or non-parametric tests were needed to analyze the data with. In this regard, normality of the mean RTs had to be first checked for each set of RTs (i.e. once for the VSWM and once for VWM). To check the normality of mean RTs, Q-Q plots and histograms for the VSWM and VWM RTs were calculated and drawn using statistical package R. The graphs and histograms have been presented in the following section.

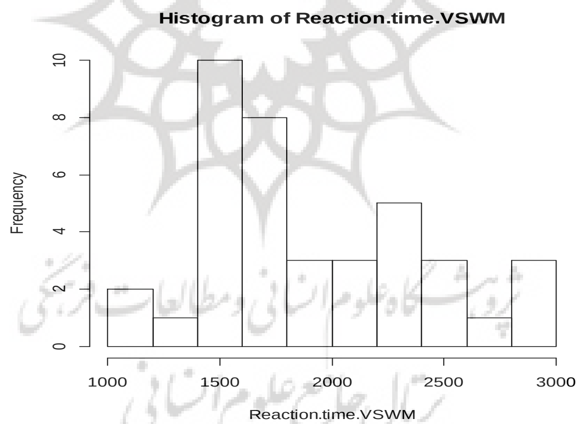

Figure 1. Histogram of mean RTs for participants in VSWM groups

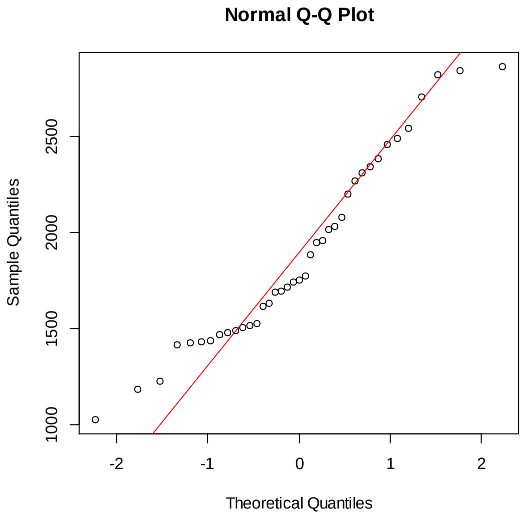

Figure 2. Q-Q plot of mean RTs for participants in VSWM groups

The Q-Q plot and histogram do not clearly indicate whether the data is normal. To further ascertain about the normality of the data, Shapiro-Wilk test of normality was calculated in R and also 5 % trimmed mean of the mean RTs of the participants in VSWM was calculated and reported. Since Shapiro-Wilk test has produced a p-value more than 0.05 (i.e. p-value = 0.07) and the 5% trimmed mean (1886.14) of the RTs is very close to the mean (1895.50), we can assume normality of data for the mean VSWM RTs.

The most powerful test to compare two groups is t-test but has some assumptions that have to be met before taking the test which are: continuous scaling for the dependent variable, sample size, normality of data, and homogeneity of group mean variances. Our dependent variable (i.e. mean RTs) are truly continuous. The sample size seems possible and the data has been shown to be normally distributed. The last assumption (homogeneity of variances) has to be checked now. The statistical package R presents some tests to check the homogeneity of variances of which the one with *var.test* code is applied to the current RTs. The test result shows the two variances are not homogeneous (F = 1.46, p-value = 0.42). Anyway, due to the power t-test has, we persist on using a t-test for the mean VSWM RTs.

Assuming the data to be normally distributed, t-test appeared to be the most appropriate test to compare the means of the groups for mean VSWM RTs. Also, since the participants were categorized into only one of the groups, the required test was an independent samples t-test. Therefore, the required t-test was taken for the participants in VSWM groups using R and the result was as follows:

	VSWM Group means		df	t	p-value
	Low	High			
Collocations RT	2059.57	1722.81	36.31	2.25	0.03

Table 4.3 T-test of collocations and (high and low) VSWM groups

The amount of p-value (0.03) obtained for the high and low VSWM groups is lower than 0.05 meaning that there is a significant difference between the two groups.

Next, to specify the most appropriate test, the same procedure had to be done for the participants in VWM groups. First, histogram and Q-Q plot were drawn and then the result of Shapiro-Wilk and 5 % trimmed mean was presented for the participants.

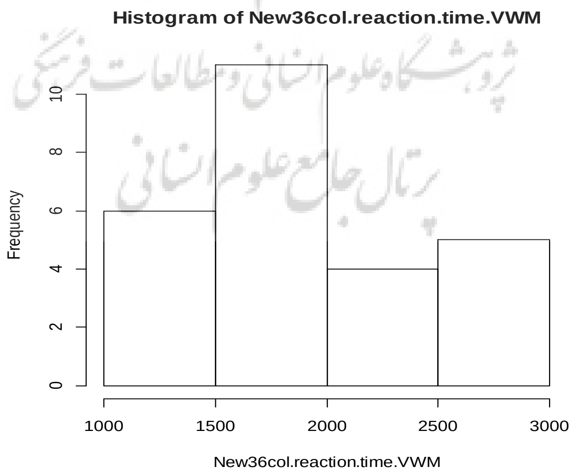

Figure 3. Histogram of mean RTs for participants in VWM groups

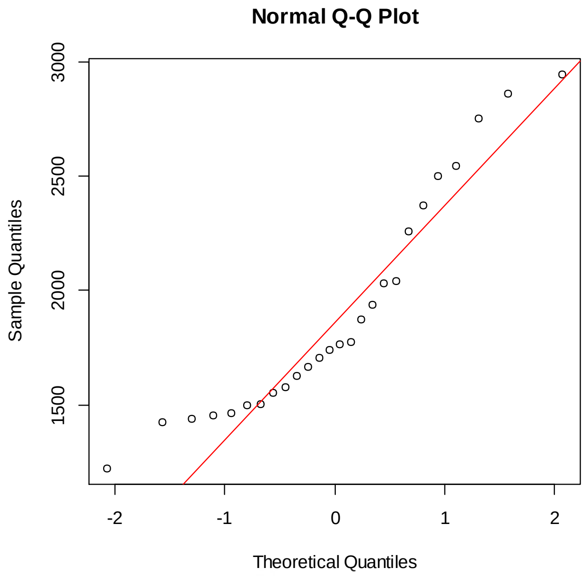

Figure 4. Q-Q plot of mean RTs for participants in VSWM groups

The result of Shapiro-Wilk test showed no signs of normality of the data since p-value = 0.01 which was lower than 0.05. Although the difference between 5 % trimmed mean (1884.05) and the mean (1905.50) was not much (i.e. 21.45), normality couldn't be assumed because no other t-tests or graphs were in line with its normality. Thus, a non-parametric test had to be used for the mean RTs of participants in VWM groups. Mann-Whitney U test seemed to be an appropriate choice.

	VWM Group means		w	p-value
	Low	High		
Mann-Whitney	2068.63	1765.68	115	0.11

Table 4.4 Mann-Whitney test of collocations and (high and low) VWM groups

The results of Mann-Whitney test showed that there was not a statistically significant difference between the two groups in their processing of collocations because the obtained p-value is more than

0.05 (w=115, p-value = 0.11). Therefore, null hypothesis of no difference is accepted.

Discussions and conclusion:

a. First research question

Since (free) collocations have simply been considered as big words in the literature, the role of working memory has been assumed to be the same for both collocations and words (Ellis & Sinclair, 1996). Also, due to the scarcity of studies on the relationship between collocations and WM span, it thus seems more reasonable to discuss some points based on the studies on the relationship between WM and vocabulary.

Literature on the relationship between WM and language has proved that only at the early stages of L1 learning Phonological Sort-Term Memory (PSTM, interchangeably used for VSTM and VWM) is highly related to vocabulary (Gathercole et al., 1999; Jarrold et al., 2004). In other words, as the child becomes more proficient in his/her L1, the link between his/her PSTM and vocabulary learning becomes tenuous (Papagno et al., 1991). Some of such studies confirming the previously attained results of effect of PSTM on vocabulary are Gathercole and Baddeley (1989, 1990), Gathercole et al. (1992), and Papagno and Vallar (1992), to name a few.

In another study, a relationship between short-term memory and word-learning abilities was witnessed (Papagno & Vallar, 1992). Furthermore, Speciale et al. (2004) conducted a study on university students and detected a contribution of both phonological sequence learning and phonological short-term memory capacity to the learning of vocabulary items. More importantly, these two variables independently had their own effects on vocabulary learning.

Interestingly, high correlation has been found between PSTM and subsequent vocabulary learning among adult L2 learners for both pre-intermediate and lower levels (Skrzypek, 2009). However, using a cross-lagged correlational paradigm, Skrzypek showed that PSTM is a causal determinant of subsequent L2 learning only at relatively early stages of L2 proficiency (i.e. elementary), and not at a more advanced level (i.e. pre-intermediate) (Skrzypek & Singleton, 2014).

The results of these studies seem convincing in considering a determinant effect of PSTM on L1 and L2 vocabulary learning for the participants with elementary proficiency in a language. Furthermore, Although this work is apparently among the first attempts in the literature to directly make a connection between restricted collocations and (upper-intermediate and advanced) participants' VWM spans, it is not getting off the way it is the case with other types of collocations and confirms the previously procured results.

b. Second research question:

In order to better discuss the points on this question, first the structure of working memory is briefly reviewed and a connection is then made to relate VWM and VSWM together. Next, the structure of the restricted collocations and its link to the right hemisphere is illuminated and finally, the reason for the attained answer is justified.

The first model on working memory (i.e. Baddeley & Hitch, 1974) proposed that there are two separate repositories for verbal and visuospatial information. It had been claimed that these two repositories named verbal working memory (VWM) and visuospatial working memory (VSWM) store information in two distinct modalities. This first one was thought to belong to auditorily heard or visually presented materials (i.e. words) and the second one contributes to the shape (visuo-) of an object and its location (-spatial).

However, in a study on picture naming, it was shown that younger children spontaneously encode the pictures visually while children do it more subvocally unless rehearsal is suppressed (Hitch, Woodin, & Baker, 1989). Also, in a study by Logie, Della Sala, Wynn, and Baddeley (2000), evidence of the existence of visual similarity effects was found in immediate recall of visually presented words. In other words, it can be argued that visual codes are to some extent involved in the temporarily storing of written information in the phonological loop.

Although it had been asserted that both auditorily heard and written words are stored in the PSTM, Chincotta and Underwood (1997) discovered that Arabic numerals (1, 3, 7) are retained better in memory than the presented digit words (one, three, seven). Moreover, studies of patients with verbal STM deficits produce more evidence on the involvement of a visual storage buffer by detecting a better span for the visually presented information than the auditorily one (Shallice & Warrington, 1970). A number of studies have also shown that there is a contribution of semantic coding to memory performance in some sequential remembering tasks (e.g. Baddeley and Ecob (1970); Hulme et al. (1997)). This process helps the phonological loop to better store information.

Taking both visual codes for written words and semantic coding of PSTM into account, it is more logical to discuss the answer obtained for the second research question. The results of the data analysis indicated a significant effect of VSTM on the retrieval speed (i.e. reaction time) of restricted collocations.

In light of the two aforementioned points, it can be argued that there are two possibilities for the answer attained for the second research question: The first possibility is that the collocations had previously been met and their meanings learned and consequently, due to the outstanding feature of such collocations (i.e. opacity), they have been perceived like idioms and metaphors (i.e. figurative language) with a fixed meaning. The second one is that the collocations had been grasped as co-occurring single vocabulary items in which due to their high semantic load for the sake of low predictability of meaning, they had to be spontaneously analyzed and understood within their sentences (i.e. context).

A necessity is felt to examine the two possibilities in detail. Regarding the first possibility, as previously mentioned, restricted collocations are seemingly acting more like idioms and metaphors in that literal meaning of the constituents does not result in what it purports such as *empty promise*. It is, nevertheless, considered as a collocation, and not an idiom, because of its substitutability feature, restricted though, compared to the unavailability of substitutability feature for idioms. Therefore, such collocations with their non-literal meaning most probably act like figurative language constructions.

With regard to the second possibility, it can be contended that if restricted collocations are perceived like single vocabulary items, they apparently put so much semantic processing load on the participants' minds that tend to be in harmony with Coarse Semantic Coding Theory (Beeman et al., 1994). The Theory suggests that in case of high semantic process load for the processing of figurative language, it is right hemisphere which takes over the responsibility; otherwise, left hemisphere is responsible. In this way, both possibilities give support to the effect of VSWM on the collocation processing which is performed within the right hemisphere.

Although the results supported previous findings in the literature for the VWM (i.e. not significant for upper-intermediate level students), an unexpected result was achieved for processing of collocations in relation to participants' VSWM spans (i.e. determinant effect of VSWM grouping on RTs of restricted collocations). The findings of this research add to the existing knowledge on the processing directions and can have implications.

A theoretical implication of this research was the unexpected discovery of interaction of language with VSWM, the component of first WM model (Baddeley and Hitch, 1974) which due to its attribution to the shape and location of objects had most of times been disregarded. Having detecting such an interaction, it could lead to a change in the somehow everlasting VWM-language relationship in the literature. This could, in turn, compel researchers to reconsider the role it could have in language learning and teaching.

In so doing, it is susceptible of having serious practical implications of which developing new materials is a notable example. Produced in this way, material development can readily produce better results for the individuals in better retaining of such collocations. In other words, learners can better learn L2 constructions via the materials addressing both channels (i.e. verbal and visual) and even there may be enhanced retention and faster processing of language using two simultaneous input receiving channels (i.e. VWM and VSWM).

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