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Exploring the Role of Proficiency as a Mediator of the Relationship between Working Memory and Text Comprehension in the L2

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Abstract

Second language (L2) learners rely heavily on working memory for both bottom-up and top-down processing due to difficulties they encounter in comprehending written or oral texts. L2 proficiency is said to mediate the relationship between WM and text comprehension in that WM's role seems to diminish at higher levels of proficiency and is observed only in tasks that require complex cognitive operations. The current study aims to examine the relationship between WM and text comprehension in relation to proficiency level and task demands through between and within groups experimental design. Reading and listening performances of intermediate and upper-intermediate learners of English were assessed at the beginning and at the end of a 14-week long semester. A reading span test in L1 was used as a measure of WM capacity. WM's relationship to L2 listening and reading was examined both across the two proficiency groups and within each group in relation to pre- and post-test

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measures. While the findings did not yield a significant relationship between WM and reading comprehension, proficiency level was found to mediate WM's effect on listening comprehension.

Keywords: Working memory, language proficiency, L2 listening comprehension, L2 reading comprehension.

Introduction

Working memory (WM) has been shown to play an important role in second language (L2) text comprehension (see Linck, Osthus, Koeth &Bunting (2014) for a review). As defined by Jackson (2020), WM is a dynamic and a complex multi-faceted system that functions as a link between storage and processing components. Research has shown that the role of WM in L2 comprehension is partly determined by learners' L2 proficiency (Gass & Lee, 2011; Mitchell et al., 2015; Wen, 2012) in that as proficiency increases, WM effects diminish. However, these studies have generally adopted between-subjects designs where students from different proficiency levels are compared. Such designs involve larger error compared to within-subjects designs. As such, the present study aimed to explore the role of language proficiency mediating the relationship between WM and L2 listening and reading by examining both intra- and inter-group differences of a group of intermediate and upper-intermediate learners of English. The listening and reading performances of learners were assessed both at the beginning and end of a 14-week long semester, and WM's relationship to L2 listening and reading was examined both across the two proficiency groups and within each group in relation to pre- and post-test measures.

Definition and Measurement of Working Memory

Originally proposed by Baddeley and Hitch (1974), WM is a limited capacity system of temporary storage and manipulation of information that is necessary for complex tasks such as comprehension and reasoning. It is a dynamic system that enables active maintenance of task-relevant information in support of the simultaneous execution of complex cognitive tasks (Baddeley, 2018). Similarly, Baddeley and Logie (1999) defined the term as storing and processing information while performing higher order cognitive tasks such as comprehension, learning and reasoning. WM has also been defined as a cognitive system that contains a limited computational space in which materials can be temporarily stored, monitored and manipulated

(Baddeley, 1986; Baddeley, 2019; Just & Carpenter, 1992). Thus, WM refers to the mental processes responsible for the temporary storage and manipulation of information in the course of on-going processing (Juffs & Harrington, 2011).

A fundamental characteristic of WM is that it has a restricted capacity, which limits cognitive performance (Swanson, 2000). Individuals with larger capacity typically perform better than individuals with smaller capacity on a variety of cognitive tasks including complex learning, reading and listening comprehension. WM capacity determines the amount of information that can be held accessible and processed (Kane & Engle, 2002; Kyllonen & Christal, 1990). Daneman and Carpenter (1980) argue that WM capacity leads to the quantitative differences among individuals in the speed and accuracy with which they comprehend language. They describe capacity as an energy source that some people have more of than others. In other words, a person with a larger memory capacity for language may be able to draw on a larger supply of resources (Just & Carpenter; 1992).

In general, WM capacity is measured by using complex span tasks that make simultaneous demands on storage and processing (Kane et al., 2004). Variations of complex span tests are, Reading Span (Daneman & Carpenter, 1980), Listening Span (Daneman & Carpenter, 1980), Counting Span (Case, Kurland, & Goldberg, 1982), Operation Span (Turner & Engle, 1989), Speaking Span (Daneman & Green, 1986), and Spatial Span (Shah & Miyake, 1996). The general structure of all complex span tasks can be defined as encoding of a list of words or letters for serial recall together with a parallel distracting processing task such as reading a sentence, making syntactic or semantic judgments, or verifying a mathematical equation. A considerable number of studies reported that scores from variants of complex span correlate well with each other (Daneman & Merikle, 1996; Kane & Engle, 2003; Unsworth & Engle, 2005).

Studies investigating the role of WM in L2 learning typically use linguistic measures such as reading/listening span tests (RST, LST) or nonlinguistic measures such as operation span tests (OST). An important issue in the measurement of WM in L2 literature concerns the language (L1 vs. L2) used in the linguistic measures. Research has shown that the storage scores from different measures correlate strongly (e.g. Osaka & Osaka, 1992; Osaka, Osaka & Groner, 1993; Alptekin, Erçetin, & Özemir, 2014), suggesting that WM is not a language-specific construct.

The Role of WM in L2 Reading

Reading is a complex process involving word recognition, comprehension, fluency, and motivation, along with a variety of cognitive processes. Reading comprehension relies on the capacity of WM to retain text information that facilitates the comprehension of succeeding sentences (Just & Carpenter, 1992). Individuals with greater WM capacities are more successful at carrying the information from one sentence to the next and integrating information during reading. There is much evidence for WM capacity as a strong predictor of reading comprehension both in L1 (Daneman & Carpenter, 1980; Miyake & Friedman, 1998) and L2 (Alptekin & Erçetin, 2011; Harrington & Sawyer, 1992; Service et al., 2002; Walter, 2004).

A number of studies conducted with L2 learners have shown a significant relationship between WM and L2 reading comprehension usually when RSTs were administered in the L2 (e.g. Alptekin & Erçetin, 2011; Harrington & Sawyer, 1992; Service et al., 2002; Walter, 2004). For instance, Walter (2004), in her study of the transfer of reading comprehension skills from L1 to L2 for upper- and lower-intermediate French learners of English, has shown that L2 reading comprehension is associated more with L2 WM capacity rather than L1 WM capacity. On the other hand, other studies provided evidence for a significant relationship between WM and L2 reading when measures other than L2 RST are used such as L1 RST (Dorcheh & Adams, 2014; Leeser, 2007; Sagarra, 2017) and OST (Rai et al., 2011).

The interaction between prior knowledge and WM in facilitating L2 reading comprehension has also been investigated. For instance, Leeser (2007) observed a significant interaction between reading span and topic familiarity for beginning level learners of Spanish, suggesting that higher WM capacity combined with higher prior knowledge allows excel in reading comprehension, whereas Alptekin and Erçetin (2011) found significant and independent contributions of L2 reading span and content familiarity to inferential comprehension, but not to literal understanding. Also, Joh and Plakans (2017) reported WM as an important predictor of L2 reading comprehension of Korean EFL learners when topic knowledge was provided. More recently, highlighting the role of WM in L2 reading in terms of using existing resources to one's advantage, Shin, Dronjic and Park (2018) reported that L2 readers with higher WMC achieved better reading comprehension than low WMC readers.

The Role of WM in L2 Listening

Listening has been defined as the ability to process spoken language automatically, to understand the linguistic information that is attached to the oral text. Listening comprehension is more than just hearing the spoken language. The listener often has to construct the meaning using linguistic knowledge, the context of the situation, and his/her background knowledge on the topic of the spoken text (Brown & Yule, 2001; Flowerdew & Miller, 2005). Hence to decode and comprehend what is spoken requires complex cognitive processes that take place in real time. In this sense, insufficient WM capacity can cause problems in listening comprehension. Despite a large body of research that focused on the relationship between WM and reading either in L1 or in L2, the role of WM for the listening process has not been sufficiently explored.

Tsuchihira (2007) assessed the listening span of junior college students in their freshman year both in L1 (Japanese) and in the L2 (English), and reported a significant relationship between L1 and L2 WM. The results also showed that both L1 and L2 listening span were related to L2 listening ability. In another study, Shanshan and Tongshun (2007) demonstrated that listening span both in L1 (Chinese) and L2 (English) were related to L2 listening comprehension of freshmen students from a Chinese University. An unpublished doctoral dissertation by Londe (2008) also reported a significant relationship between L1 listening span and L2 listening comprehension for Hungarian college learners of L2 English at various levels of proficiency. Mackey, Adams, Stafford and Winke (2010) observed a meaningful relationship between listening span of English-speaking learners of Spanish and their production of modified output. In other words, listening span capacity accounted for 17–18% of the variance in the listening scores. On the other hand, Andringa, Olsthoorn, van Beuningen, Schoonen and Hulstijn (2012), in their investigation of individual differences in listening comprehension of L2 speakers of Dutch, observed that WM did not explain unique variance in listening comprehension.

The role of WM in L2 listening comprehension has not been studied as extensively as that in L2 reading. Besides, to what extent the proficiency level of the learners affect the relationship between WM and listening comprehension in a developmental process is also unresolved both for L2 reading and listening. As such, understanding whether WM's role in L2 listening and reading changes based on the learners' proficiency level has yet to be explored.

L2 Proficiency and WM

Growing evidence indicate that L2 production and comprehension demand more cognitive resources compared to language processing in the L1 (Vandergrift & Baker, 2015). Moreover, when a comparison is made among L2 learners, learners with lower proficiency level in the target language need more WM resources when compared to more proficient learners. Therefore, understanding the interaction between L2 proficiency level and WM capacity will be helpful in making inferences about text comprehension in the target language.

A number of studies investigated the interaction between WM and language proficiency. Focusing on a multilingual context, Van den Noort, Bosch, and Hugdahl (2006) examined the issue with a group of multilingual participants who were native Dutch (L1) speakers fluent in German (L2) and had recently started learning Norwegian as their third (L3) language. The results from two complex WM tasks (reading-span task and letter-number ordering) revealed that the functional WM capacity of the participants was the largest in the L1 and was larger in L2 than in L3.

Gilabert and Munoz (2010) investigated whether WM capacity could explain differences in general proficiency and performance (fluency, structural and lexical complexity, and accuracy) of high-intermediate/advanced learners of English. They used an L1 (Spanish) RST as a measure of WM and a complex narrative task (a film retelling task) as a measure of their oral production. The results revealed no correlation between WM scores and overall language attainment confirming that learners may progress in the learning of an L2 regardless of their WM capacity and individual differences in WM alone cannot explain the different levels of achievement, and should therefore be combined with other variables. On the other hand, they also observed a significant relationship between WM and performance in the complex narrative task for the high proficiency group (r = .531), but not for the lower proficiency group. They concluded that higher WM capacity is associated with faster lexical access and retrieval and a certain level of proficiency in the L2 has to be attained for a possible WM advantage.

In another study, Shahnazari-Dorcheh and Adams (2014) investigated the relationship between learners' WM scores based on an L1 RST (Persian) and L2 reading comprehension across three proficiency levels (beginning, intermediate, and advanced). They used two expository tests to measure reading comprehension and an L1 RST as the WM measure. Multiple regression analysis for the data from 55 L1 Persian EFL learners revealed a significant correlation between WM capacity and reading ability at beginning level of proficiency. They reported WM capacity as a potential source of individual differences in explaining L2 reading ability at the beginning level. They concluded that the relationship between working memory and L2 reading disappears as the proficiency increases in that low-proficiency L2 learners rely on WM more than high-proficiency L2 learners during reading.

Serafini and Sanz (2016) carried out a longitudinal study withL2 learners of Spanish at a range of L2 proficiency from beginner to advanced levels. They assessed WM capacity by two nonverbal span tasks namely an OST and a digit span task in the learners' L1. Additionally, an elicited oral imitation task and an untimed grammaticality judgment task were used to measure learners' ability to process and use L2 Spanish grammar both in comprehension and production. The participants were tested at the beginning of the instruction, at the end of a 10 weeks instruction, and four weeks after a period without instruction with two sessions at each testing time. For beginning and intermediate learners, the findings revealed positive WM effects for grammatical development. On the other hand, for the advanced group with the most practice in L2 Spanish, WM capacity played a minimal role in explaining L2 development. This effect has been explained in relation to the diminishing role of WM over time. The strength of relationships found in the beginner and intermediate groups varied over time. The strong relationship at the outset of the instruction turned into a relatively weaker relationship at the end of the instruction. The authors concluded that a semester of exposure to L2 in a classroom setting may have neutralized the facilitative role of WM.

Sagarra (2017) investigated the role of WM in L2 development over one year (Experiment 1) and one semester (Experiment 2) by focusing on beginner level L1 English learners of Spanish. The study explored a possible effect of WM on L2 grammar learning and reading comprehension by utilizing a RST in L1 with a self-paced easy processing task (Experiment 1) and a RST in L1 with a difficult processing task performed under time pressure (Experiment 2). Grammar and reading tests were administered both prior to and at the end of the course. The results of the first study revealed non-significant correlations between WM and any of the linguistic tests. However, in the second study, RST scores were positively related to L2 learning of grammar and reading since it included a taxing processing measure. The study concluded that WM has a long-term effect on L2 development of grammar and reading in early stages of learning, although this effect disappears in WM tests without a cognitively demanding processing task.

A meta-analysis by Linck et al. (2014) carried out a quantitative synthesis of studies that focused on the effect of WM on L2 processing and proficiency in the last two decades. Analysis of the data from 79 samples aimed to estimate the mean of the population distribution of effect sizes and to generalize the results beyond the sample of examined studies. Their analysis indicated that WM is positively associated with both L2 processing and proficiency outcomes. They reported that low proficiency L2 learners with larger WM capacities performed significantly better than those with lower span scores on tasks addressing L2 processing abilities. However, significant L2 processing advantages for learners with higher WM scores for highly proficient bilinguals were not found in several studies. The results were congruent with claims that WM is an important component of the cognitive processes underlying bilingual language processing and performance on measures of L2 proficiency. However, they also pointed to the importance of further studies to examine the link between specific language processes, in order to advance theoretical models and further our understanding of the contributions of cognitive capacity on L2 attainment.

Considering all the abovementioned studies, it is clear that, research on the relationship between WM and language attainment yielded contradicting findings about the contribution of cognitive capacity on bilingual language processing and performance, probably due to the use of different types of WM span tasks and different measures of L2 performance. Additionally, the role of language proficiency as a mediator of the relationship between WM and L2 development has yet to be established.

Aims and Hypotheses

The following research question was investigated: How do intermediate and upper-intermediate learners with high- vs. low-WM capacity differ in terms of listening and reading comprehension at the beginning and end of an academic semester? In view of available research findings pointing to a meaningful relationship between WM capacity and reading comprehension (e.g., Alptekin & Erçetin, 2009, 2010, 2011; Harrington & Sawyer, 1992; Miyake & Friedman, 1998; Walter, 2004) as well as WM capacity and oral language comprehension/production (e.g., Juffs & Harrington, 2011; Kormos & Safar, 2008; Mackey, Adams, Stafford, & Winke, 2010), learners with larger capacities were expected to have better listening and reading comprehension scores (Hypothesis 1). It was also hypothesized that since WM operates through conscious controlled processes, its role was expected to be stronger with intermediate learners (Hypothesis 2) whose language skills are less proceduralized and before instruction (Hypothesis 3) when skills are less automatic (Erçetin & Alptekin, 2012).

Method

Participants

The participants were Turkish University students who received course credit for participating in the study. All of the participants were native speakers of Turkish, with ages ranging from 18 to 22. They formed two different proficiency levels: a) 86 students in the intensive English program (55 female and 31 male), and b) 87 junior students from the departments of English Language Teaching and English Language and Literature (56 female and 31 male). According to the regulations of the university, at the beginning of the term, all incoming students from English Language Teaching (ELT) and English Language and Literature (ELL) departments are given a placement test including grammar, reading, essay writing, listening, and speaking sections. Participants who pass the placement exam are enrolled as freshmen. Students who get scores below 60 points have to attend an intensive English program for one academic year. The students in the intensive English program take 8 hours of Basic English grammar, 7 hours of listening and speaking, 7 hours of reading, and 4 hours of writing courses, with a total of 26 hours per week. According to the Common European Framework of Reference for Languages (CEFR) the participants from the first group are considered at B1 level (intermediate) whereas the second group of participants are considered at B2 level (upper-intermediate) (CEFR, 2001a).

Instrumentation and procedures

Measures of Reading and listening comprehension

Both the reading and listening exams were taken from Exam Essentials: CAE Practice Tests (Osborne, 2006). The reading section of the CAE consisted of 4 sub-sections. In section A there were 2 multiple choice reading comprehension questions for each of three short passages, with a total of 6 questions. Section B comprised 7 multiple choice reading comprehension questions for a longer passage. Section C consisted of a magazine article in which six paragraphs were removed. The participants had to choose the right paragraph, which fits best to each gap. In Section D, there were 15 questions and the participants had to choose which question was related to any of the given category. The total number of questions was 34. Each correct answer was awarded 1 point.

The listening test of the CAE included 4 sections. In Section A, the participants listened to three different extracts, and they had to choose the answer (A, B, or C) which fitted best according to what they heard. There were two multiple-choice questions for each extract. In Section B the participants were asked to listen to part of a talk and complete the sentences with the appropriate word. There were 8 fill in the blanks questions. In Section C, the participants listened to an interview and chose the best answer for 6 multiple-choice listening comprehension questions. In Section D, the participants had to accomplish two tasks. For each part, they listened to five short extracts and were asked to choose from the list of what each speaker talks about in relation to a certain topic. There were 5 questions for each task. There were 30 questions for the listening part. Each correct answer was awarded 1 point. With reference to the standard application of CAE, the participants were given 75 minutes for the reading section, and 40 minutes for the listening section.

Reading Span Test in L1

The RST in Turkish was developed by Alptekin & Erçetin (2010). The test consisted of 42 unrelated simple sentences in the active voice. Each sentence ended with a different word. Since word order in simple Turkish sentences is generally '*Subject Object Verb'*, the sentences in the test always ended with a verb. All the verbs were motion verbs and third person singular. Each sentence was 11–13 words in length, presented on-line by displaying one sentence after another at 7-second intervals. As a processing task, a syntactic judgment task was used to ensure that participants process every sentence for syntax rather than focusing only on the final words. As such, the test included 21 grammatical and 21 ungrammatical sentences. During the test the participants pressed "T" on the keyboard to indicate whether a given sentence was grammatical or "F" for ungrammatical. The test consisted of five sets of sentences. Starting from two sentences, the set size increased to five sentences with three practice trials for each set size. Once all the sentences for a set are displayed, a question mark appeared on the empty screen and the participants were asked to write down the last word of the sentences in a set. Cronbach's α for the internal consistency reliability coefficients for the processing and storage tasks were found to be .972 (M = 26.82, SD = 13.62) and .973 (M = 25.63, SD = 13.93) respectively.

The RST was scored by following the same procedure suggested by Waters and Caplan (1996). Word recall and sentence judgment scores were converted to z-scores to obtain composite scores and their average was taken. The participants were divided into the low- and high-WM groups based on a median-split procedure. Thus, the participants below the median were categorized into low-WM group while those above the median were categorized in the high-WM group.

Procedures for data collection and data analysis

The data were collected in 3 sessions during the 14-week semester. The first session was carried out during the first week of the semester and consisted of the CAE including one reading comprehension and one listening comprehension test. For each group of participants, the CAE tests were administered in groups and supervised by the researcher. After two weeks, in session 2, the participants completed the RST. Session 3 was carried out during the last week of the semester and a modified version of the CAE test was administered as a post-test which was at the same level and with the same task types as in the pre-test. For each group of participants, the CAE tests were administered in groups and supervised by the researchers.

For the analysis of the data, the storage scores (i.e., the total number of accurately recalled sentence-final words in the L1 RST) constituted the WM measure. For each WM measure, the participants were divided into low- and high-WM groups based on a median-split procedure on the storage scores. Thus, the participants below the median were categorized into low-WM group while those above the median were categorized in high-WM group. In order to answer the research questions, descriptive statistics were first obtained. Then, 2x2x2 mixed ANOVAs were conducted separately on listening and reading scores with time of testing (pre vs. post) as the repeated measures factor, WM capacity (low vs. high), and proficiency level (intermediate vs. upper-intermediate) as between groups factors. The statistical procedures were carried out via IBM SPSS Statistics 20.0.

Results

Table 1 presents the descriptive statistics for pre- and post-test listening and reading scores across proficiency levels and WM groups. The mean difference between low- and high-WM participants is worth noting especially in the intermediate group and in terms of listening comprehension, while the difference seems negligible in the upper-intermediate group in terms of both listening comprehension and reading comprehension.

Table 1. Descriptive statistics for listening and reading tests

			Pre-test		Post-test		
Test	Proficiency	WM	M	SD	M	SD	N
Listening	Intermediate	Low	7.55	2.69	9.14	2.05	27
		High	9.27	2.60	9.46	2.57	43
		Total	8.61	2.75	9.34	2.37	70
	Upper-Intermediate	Low	10.65	2.65	10.80	1.60	26
		High	12.62	2.87	9.75	1.38	8

		Total	11.11	2.79	10.55	1.59	34
Reading	Intermediate	Low	11.32	2.55	13.03	3.01	28
		High	11.23	3.04	12.72	2.66	43
		Total	11.26	2.84	12.84	2.79	71
	Upper-Intermediate	Low	10.04	2.40	14.16	2.40	25
		High	10.62	1.84	14.12	1.88	8
		Total	10.18	2.27	14.15	2.26	33

The ANOVA results for reading comprehension indicate a significant main effect of time of testing and a significant interaction between time of testing and proficiency level (Table 2). Unlike listening comprehension, the main effect of WM on reading comprehension was not significant nor was the interaction between time of testing and WM.

Table 2. ANOVA summary table for reading comprehension

Source	S	f	S	F	Sig.	Partial ŋ²
Proficiency	.913	1	.913	.10	.742	
WM	.048	1	.048	.00	.940	
Proficiency * WM	2.030	1	2.030	.24	.624	
Error	837.918	100	8.379			
Time	261.486	1	261.486	43.68	.000	.304
Time * Proficiency	43.561	1	43.561	7.27	.008	.068
Time * WM	1.597	1	1.597	.26	.607	
Time * Proficiency * WM	.347	1	.347	.05	.810	
Error(time)	598.549	100	5.985			

The interaction between time of testing and proficiency level is illustrated in Figure 1, which shows that the intermediate group has a slightly higher pre-test mean than the upper-intermediate group. On the other hand, the reverse is the case on the post-test. Tests of simple main effects with Bonferroni adjustment revealed that the difference between the two groups was not significant ($p > .05$) at Time 1 while it was significant at Time 2 ($p < .05$). In other words, the groups did not differ in reading performance before instruction. After instruction, the upper-intermediate group surpassed the intermediate group.

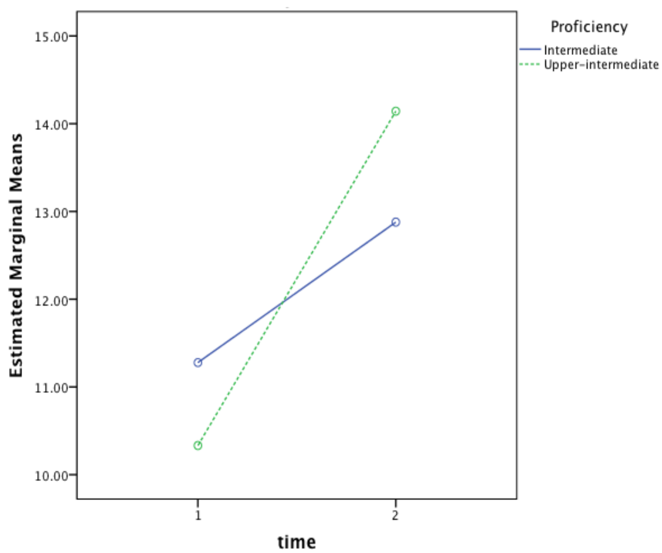

Figure 1. The interaction between time of testing and proficiency level for reading comprehension

As for listening comprehension (Table 3) point to a significant main effect of proficiency level as well as a significant interaction between time of testing and proficiency level. Also, there is a significant interaction between time of testing and WM capacity. The other effects were not significant.

Table 3. ANOVA summary table for listening comprehension

Source	S	f	S	F	Sig.	Partial ŋ²
Proficiency	157.247	1	157.247	21.33	.000	.176
WM	19.499	1	19.499	2.64	.107	
Proficiency * WM	2.838	1	2.838	.38	.536	
Error	737.076	100	7.371			
Time	1.985	1	1.985	.45	.501	
Time * Proficiency	45.246	1	45.246	10.38	.002	.094
Time * WM	43.960	1	43.960	10.09	.002	.092
Time * Proficiency * WM	5.881	1	5.881	1.35	.248	
Error(time)	435.645	100	4.356			

Figure 2 shows the interaction between time of testing and proficiency level. The mean of the intermediate group increased significantly from the pre-test to the post-test ($p < .05$) whereas that of the upper-intermediate group decreased slightly (p> .05). The mean difference between the intermediate and upper-intermediate group is much larger on the pre-test compared to the post-test. Tests of simple main effects with Bonferroni adjustment revealed that the difference between the two groups was statistically significant both before instruction (p< .001) and after instruction (p< .01). In other words, the upper-intermediate group outperformed the intermediate group at both times of testing.

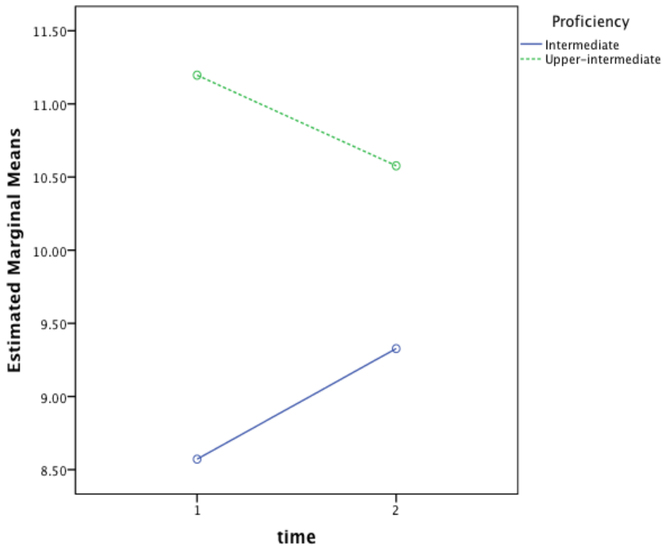

Figure 2. The interaction between time of testing and proficiency level for listening

The interaction between time of testing and WM capacity is illustrated in Figure 3, which indicates that the difference between low- and high-WM learners is greater on the pre-test compared to the post-test. Tests of simple main effects with Bonferroni adjustment revealed significant differences between the two groups at Time 1 (p< .01) but not at Time 2 (p > .05), suggesting that the effect of WM capacity on L2 listening comprehension decreases as the proficiency level increases.

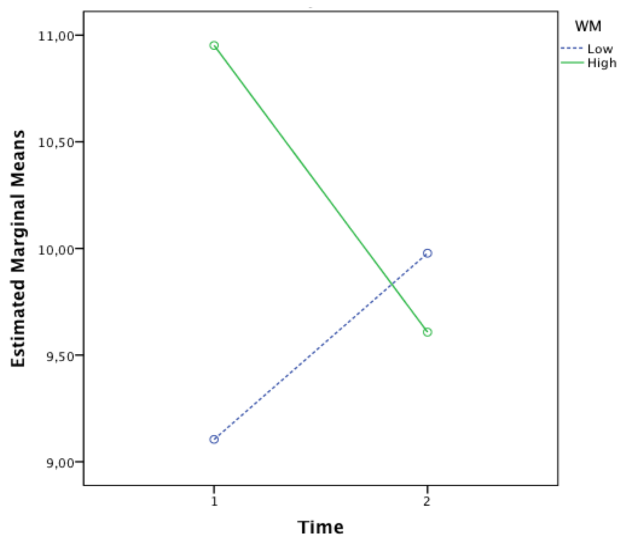

Figure 3. The interaction between time of testing and WM for listening

To summarize, findings point to significant effects of WM on listening comprehension but not on reading comprehension. Specifically, the difference between the low- and high-WM learners is greater on the pre-test compared to the post-test, suggesting that WM role in L2 listening comprehension decreases as the proficiency level increases.

Discussion

Findings indicate that WM has a significant relationship with listening comprehension but not with reading comprehension. The meaningful relationship between WM and listening comprehension corroborates with other studies in the field. For instance, Kormos and Safar (2008) showed that WM capacity measured by a complex span task correlated very highly with overall English language competence including listening test scores of students. Similarly, Tsuchihira (2007), Shanshan and Tongshun (2007), and Londe (2008) concluded that learners with larger WM capacities were more likely to have better abilities in listening comprehension based on the significant relationship of listening comprehension with both L1 and L2 WM capacities.

The findings regarding the lack of a relationship between reading comprehension and WM capacity do not support the findings of studies demonstrating the existence of such a relationship either in L1 (e.g., Daneman & Carpenter, 1980; Daneman & Merikle, 1996) or L2 (e.g, Alptekin & Erçetin, 2009, 2010, 2011, Harrington & Sawyer, 1992; Leeser, 2007; Miyake & Friedman, 1998; Walter, 2004). On the other hand, the findings are in line with a number of studies that point to the lack of a significant relationship between WM and L2 learning. For instance, Juffs (2005) found that overall scores based on the Michigan Test's grammar and vocabulary sections did not correlate with either L1 or L2 RST scores. This finding was consistent for learners from different L1 groups, namely Chinese, Japanese, and Spanish. Shahnazari-Dorcheh and Adams (2014) investigated the role of WM in L2 reading comprehension with regard to different proficiency levels and demonstrated a significant relationship for the beginner group but not for the intermediate and advanced learners.

Thus, WM's role seems to depend on how challenging the reading task is for the learner group. In this regard, treating the concept of reading comprehension as a two-dimensional construct, Alptekin and Erçetin (2010) demonstrated that WM was significantly associated with inferential comprehension for advanced learners of English while its relationship to literal comprehension was not significant. They concluded that unlike literal understanding, inferential comprehension requires controlled and effortful processing even for proficient L2 learners. Thus, the way reading comprehension is conceptualized is crucial in exploring how it is related to WM capacity.

As for the role of proficiency level, cross-sectionally, the effect of WM was observed neither on listening comprehension nor on reading comprehension since the interaction between WM and proficiency groups was not statistically significant. Developmentally, it was observed that, regardless of proficiency level, the difference between low- and high-WM learners was greater on the pre-test compared to the post-test for listening comprehension but not for reading comprehension since the interaction between WM and time of testing was significant for the former, not for the latter. The cross-sectional and developmental comparisons seem to contradict each other. This could be explained by low degrees of reliability in the placement of learners into proficiency groups. Although the results of the current study shows that the proficiency groups were somewhat different in their listening and reading performance, error associated with placement decisions based an institutional placement test as in the current study, might contaminate the results. Additionally, proficiency level differences between the two groups may not be large enough; a comparison of the intermediate group with an advanced group might have revealed different results. Therefore, the developmental results may be more dependable. As such, it can be concluded that, while no effect of WM is observed on L2 reading comprehension, the level of proficiency mediates its effect on listening comprehension. Specifically, WM seems to be more influential at lower levels and its effect weakens, as skills get more automatic. In other words, since WM operates through conscious controlled processes, its effect is stronger at lower levels. Learners, unlike reading, cannot regulate their pace during listening since the procedure requires simultaneous processing of the received input (Just & Carpenter, 1987). Listeners create understanding by starting with the smallest units such as individual sounds, or phonemes that are combined to form words in order to compose phrases, clauses, and sentences. Finally, individual sentences are combined to create ideas and concepts to make the aural input comprehensible. Hence, during all these stages of L2 listening there isa great demand on WM. In other words, less proficient language learners spend much of their WM capacities on holding information in their memories while processing listening comprehension tasks. As learners proceduralize their L2 skills (Ullman, 2005), they rely less on their WM capacities (Carpenter, Morgan-Short, and Ullman, 2009).In other words, more proficient learners can process the spoken information more easily and share more cognitive resources to operationalize the information representations. As a result, it becomes evident why the role of WM in L2 listening comprehension weakens as learners get more proficient.

Pedagogical implications

As discussed above, the capacity and effective functioning of WM facilitates the rate and extent of learning. As a result of this, classroom performance and the development of academic skills, such as reading comprehension and listening comprehension rely heavily on the sufficient functioning of WM resources. In typical language classroom learning environments, common classroom activities involve the potential to impose heavy demands on storage and processing. Hence, learning becomes less successful when WM capacity is overloaded by activities in which new information needs to be integrated with previously stored knowledge simultaneously. Therefore, it is critical for material developers to design effective language tasks for learners from lower language levels. Thus, both oral and written texts should be designed considering the limited capacity of WM. As such, the amount of cognitive load that can be caused by any learning material in the L2 should be taken into account during the stages of material development and presentation of it.

Theoretically, this argument is based on Sweller's (1988) Cognitive Load Theory of learning, which postulates that because of its limited capacity architecture, if the WM resources are not used efficiently, the cognitive load on WM capacity would deteriorate learning. Sweller (1988) defines mental load as the load that is created by the characteristics of a particular task in question while mental effort is the amount of cognitive capacity or resources allocated by the learner to do a given task. Therefore, the cognitive load that is created by the instructional design of any learning material (extraneous cognitive load) should be decreased through carefully designed materials.

Additionally, the intrinsic cognitive load, i.e. the load due to the complexity of the task depends of the level of background knowledge required by the task. In language learning, proficiency level is an important factor related to intrinsic load since L2 learners have to achieve the given task and process the target language at the same time. For this reason, L2 learners with low-WM capacity are likely to experience cognitive overload, which might prevent them from forming meaningful representations required to successfully accomplish complex tasks. Gerjets, Scheiter and Catrambone (2004) suggested that, confronting the learners with simplified tasks including lower element interactivity at the onset of learning, results in a lower level of intrinsic cognitive load when learning how to accomplish complex tasks. They also suggest that providing examples for complex tasks, significantly decreases the number of elements that have to be considered at the same time and help lowering intrinsic cognitive load. Also, in order to avoid failure during comprehension activities, complex tasks can be reduced by breaking down the tasks into separate steps, so that learners use their WM capacity more effectively (Alloway, 2006). Language teachers can also simplify vocabulary by using common words rather than unusual, use simplified forms of sentences rather than sentences with complex structures; and reduce the sentence length.

Another way to lower the intrinsic cognitive load for L2 learners is to engage them in tasks that facilitate automaticity in lower-level listening/reading skills, which would help learners allocate their WM resources to higher level comprehension skills. Automatic identification of any linguistic element is an important prerequisite for efficient higher-level language processing. Learners who develop automaticity in basic language skills are likely to become more proficient at higher levels of language processing. Finally, strategy training in listening and reading can also help learners in allocating their attention to higher-level skills in reading or listening in the L2. Specifically, teaching explicit techniques such as scanning, skimming, previewing and questioning strategies can help learners with text comprehension since the process of reading is interactive and strategic in nature (Oxford 1990). As for listening comprehension strategy training should involved note taking, using graphic organizers, and focusing on key words and facts (O'malley, Chamot and Küpper, 1989). Strategic learners are more likely to use their WM resources in performing higher-level skills.

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