The Effect of L1 and L2 Working Memory on L2 Listening Comprehension

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Abstract

The role of working memory in L2 listening comprehension was investigated. The study also investigated the extent to which this role varies across L2 proficiency levels. 210 Japanese EFL learners completed L1 and L2 digit span tasks, listening span tasks, and L2 listening comprehension tasks. A correlation analysis showed that both L1 and L2 working memory capacity was related to L2 listening, but that the predictive power of L2 working memory capacity was larger than that of L1 working memory capacity. The main findings in the multiple regression analysis were (a) L2 working memory capacity accounted for a significant 19.2 % of unique variance in L2 listening comprehension for the most proficient L2 users, and (b) L1 working memory capacity accounted for a significant 21.7 % of unique variance in L2 listening comprehension for the least proficient L2 users.

1. Introduction

L2 listening comprehension is probably the least understood and least researched of all four language skills because it is least explicit in nature and because of the difficulty in accessing the process (Vandergrift, 2004, 2007). It is not simply a process of decoding language but it also involves complex cognitive processes at different levels (Buck, 2001). According to Just and Carpenter's (1992) capacity theory, any listener's cognitive processes are in competition for limited processing resources. L1 listeners will have processing capacity to spare, because they can process aural input automatically, with little conscious attention to individual words. On the other hand, lower-level L2 listeners who have limited linguistic knowledge are forced to devote more cognitive resources to lexico-grammatical processing, because they process little of what they hear automatically. They need to consciously focus on individual words they hear, given the limitation of their working memory (Lunch, 1998; Vandergrift, 2004, 2007). In this case, 'lower-level processes will be privileged at the expense of higher-level processes' (Zwaan & Brown, 1996, p.291). Current models for L2 comprehension accept a trade-off between the storage and processing functions of working memory (Lynch, 1998; Miyake & Carpenter, 1994). Working memory (henceforth, WM) is involved in the simultaneous storage and processing information during the performance of complex cognitive tasks (Baddeley, 2007). In the case of listening, the acoustic input is held briefly in echoic memory, and then processed by a central executive component of WM (Buck, 2001). In contrast to long-term memory which is unlimited, WM is of limited capacity. According to Just and Carpenter's theory (1992), WM capacity constrains comprehension and the capacity for activation-mediating processing and storage varies among individuals. People who have better WM capacities could be expected to learn an L2 more efficiently, and under this expectation, the capacity should predict learning rate and ultimate levels of attainment in L2 (Ortega, 2009).

WM capacity is considered to play an important role in the component processes involved not only in L1 but also L2 performance and development (Harrington & Sawyer, 1992; Miyake & Friedman, 1998). More specifically, it has been found that there is a positive correlation between WM capacity and specific L2 skills, such as L2 reading comprehension (Alptekin & Ercetin, 2010; Geva & Ryan, 1993; Harrington & Sawyer, 1992; Miyake & Friedman, 1998; Waters & Caplan, 1996), and L2 syntax (Harrington & Sawyer, 1992; Miyake & Friedman, 1998). It has also been reported that WM capacity is related to the ability to control attention (Engle, 2002) and the efficiency of information processing (Osaka, 2000). However, despite the importance of WM capacity, there is little published research distinguishing the information processing and storage function of it, especially in the listening process. Based on an assumption that the limited capacity of WM could affect successful integration of overall processing skills in L2 listening, the present study aims at examining the contribution of WM capacity and short term memory (henceforth, STM) capacity to the processing of L2 listening with both advanced and elementary L2 users.

2. Background

2.1 Framework of WM

Among the variety of models of WM, one of the most influential is Baddeley's multi-component model (Baddeley, 2000, 2007). This basic model is composed of a multi-component memory system consisting of the central executive, which coordinates two modality-specific subsystems, the phonological loop, and the visual-spatial sketchpad. The central executive has several functions including attention control, coordinating storage, the processing of information, and activating representation within long-term memory (Baddeley, 2007). The visual sketchpad works with visual and spatial information. The phonological loop is comprised of two additional subsystems: a phonological store and a subvocal rehearsal process. The phonological store holds representations of auditory information for a few seconds, and an articulatory rehearsal process, which refreshes decaying information. The subvocal rehearsal process is capable of rehearsing the information in the phonological loop, resulting in a limited span of immediate memory. Later, a fourth component was added to the model: the episodic buffer, which uses multi-dimensional coding, combines the auditory and the visual codes and integrates information with representations from long-term memory to form episodes (Baddeley, 2000, 2007).

WM is related to both automatic and control processing. However, more importantly, the central executive control component of WM supports controlled processing (Ortega, 2009). Based on the assumption that WM capacity is distinguishable from a storage function, Engle (2002) argues that WM capacity is not directly related to memory, and defines WM capacity as the greater ability to control attention in order to maintain or suppress information and to avoid distraction. Cowan (1999) also argues that WM comprises the contents of short-term memory and controlled attention. Engle, Tuholski, Laughlin, & Conway (1999) state that if the shared variance between short-term memory capacity and WM capacity reflects storage, the residual of WM capacity should reflect controlled attention. Both the storage and controlled attention aspects of WM are assumed to play a critical role in the listening process by storing the result of the listeners' comprehension as they direct attention to the important information in a spoken discourse, all at the same time.

2.2 Measuring the Storage and Processing Aspects of WM

A variety of WM tasks predict a wide range of higher-order cognitive performance including reading and listening comprehension (Engle, 2002). Both the storage and processing aspect of WM capacity can be measured separately or in combination (Juffs & Harrington, 2011). The simple short-term storage capacity of WM can be measured by passive WM tasks such as digit span recall tasks, word-span tasks, non-word repetition-span tasks, and sentence repetition tasks. Considerable research has addressed the relationship between short-term memory (henceforth STM) measured by these passive span tasks and L1 or L2 learning (e.g., Call, 1985; Service & Kohonen, 1995; Scott, 1994; Williams, 2005). On the other hand, the processing capacity of WM can be measured by the complex WM tasks (Colom et al. 2006) that place demands on both the storage and processing functions. A widely used complex test is the sentence span task developed by Daneman and Carpenter (1980), which claims to measure the ability to process multiple sentences and maintain information in short-term memory storage simultaneously. Depending on the version of the sentence span task, the sentences are presented either visually (Reading Span) or auditorily (Listening Span). Whether passive or complex measures of WM are more suitable for the research of memory and L2 learning is an interesting question in second language acquisition. However, interest in aptitude and memory research has recently been shifting from passive WM capacity to complex WM capacity (Ortega, 2009).

2.3 Relation between L1 and L2 WM Capacity

The findings of the research that addressed the parallelism between L1 and L2 WM capacity suggest that cognitive resources underlying WM capacity are shared by the two languages and the relationship is language-independent (Osaka & Osaka, 1992; Osaka, Osaka, & Groner, 1993). Osaka and Osaka found a high correlation (r =.72) between L1 (Japanese) Reading Span Test and L2 (English) Reading Span Test (henceforth, RST) with highly skilled L2 users. Osaka et al. (1993) also confirmed a high correlation (r =.85) between L1 (German) and L2 (French) RST with highly proficient bilinguals. As Miyake and Friedman (1998) state, L2 processing may share the same WM resources as L1 processing at least in bilingual-level L2 users. In other studies, for example, the correlations between L1 (Japanese) and L2 (English) RST were found to be .39 (Harrington & Sawyer, 1992) and .47 (Miyasako, 2006). Most of the previous studies were conducted with proficient L2 users. In the case of lower-level L2 users, however, the relationship between L1 and L2 WM capacity might be lower, because the same task represents a greater task demand for lower-level L2 users than for higher-level L2 users (Sagarra, 2008). In this regard, Vanden Noort, Bosch, and Hugdahl (2006) investigated the interaction between WM capacity and language proficiency level with fluent German (L2) users of Dutch (L1) speakers who learned Norwegian (L3). The results showed that performance in L1, L2 and L3 RST increased in relation to their language proficiency level.

2.4 WM and L2 Performance

The results from recent studies of the individual differences in WM capacity among relatively advanced L2 learners suggest that WM capacity is related to L2 proficiency. Harrington and Sawyer (1992), for example, found a significant correlation between participants' reading span scores in their L2 and their performance in the Grammar and Reading sections of the TOEFL test. They also showed that the validity of the complex WM tasks they used (Reading Span Test) was higher than the passive WM tasks (Digit and Word Span Test). While L2 RST scores had significantly strong correlations with the TOEFL Grammar (r =.57, p <.001) and TOEFL Reading (r =.54, p <.001), the L2 English digit span and word span measures did not correlate significantly with the TOEFL measures. However, they incorporated a timed grammatical judgment task in their reading span test, whereby the participants were asked to judge whether the target sentence made sense both syntactically and semantically. Ortega (2009) argues that the grammatical judgment task, administered to the participants in the L2, relied heavily on L2 reading skills. A more recent study (Shiotsu, 2010) which has addressed components of L2 reading also showed a weak correlation (r =.15, p <.05) between WM as measured through Osaka and Osaka's (1992) L2 RST and reading comprehension measured via the paper-based test which consists of four reading passages and a total of 20 4-choice multiple choice questions.

Although the role of WM measured by RST in L2 reading has been studied, as cited above, relatively little research has focused on the role of working memory measured by the Listening Span Test (henceforth, LST) in the processing of L2 listening. The only study available on the role of WM in L2 listening for Japanese EFL university students, according to the current author's search, was conducted by Sakuma (2004). The results showed some moderate correlations between L2 LST scores and the listening dialogue, the listening passage, and the grammar sections in the "English Language Proficiency Test" which is comprised of six sections.

3. Research Questions

Based on the assumption that the central executive component of WM plays a greater role in L2 listening comprehension than the simple storage component of STM, and the role differs across L2 proficiency levels, the present study was to explore the role of L1 and L2 WM in L2 listening comprehension with both advanced and beginner L2 learners through LST in L1 (Japanese) and L2 (English). The following research questions were investigated:

RQ1: Does individual difference in WM capacity and STM capacity influence L2 listening comprehension?

RQ2: How does the role of L1 and L2 WM differ across L2 proficiency levels?

4. Method

4.1 Participants

Participants in this study were 210 Japanese 1st and 2nd year students from a technical college in Japan. Their major was English language and their level of English proficiency ranged from 195 to 970 on the TOEIC test (Mean = 417.6, SD=148.3). Before participating in the research, participants were asked to read and sign a consent form.

4.2 Instruments

4.2.1 L2 Listening Comprehension Test

In this study, the listening section of the TOEIC test was taken by the participants as a measurement of L2 listening comprehension. The TOEIC listening test comprises 100 multiple choice questions, each of which has three or four options.

4.2.2 L1 and L2 Listening Span Test (LST)

In the present study, the L1 measure of WM capacity was the Japanese version of the LST (Endo & Osaka, 2011), and the L2 measure of WM capacity was the ESL version of the LST developed by Ushiro and Sakuma (2000). Both of the LST tasks were conducted from the two-sentence condition to the five-sentence condition. Three sets of sentences were presented in each sentence condition. Scoring was conducted based on the total number of target words recalled correctly rather than traditional span scores.

4.2.3 L1 and L2 Digit Span Test (henceforth, DST)

Short-term memory was measured through L1 and L2 random digit span tasks (Joyce, 2008). In both cases, after hearing each string of digits, the participants attempted to reproduce a sequence of numbers on an answer sheet. There were 16 items in both measures.

4.3 Procedure

The study was conducted in July 2011. The TOEIC test was administered to all the participants on the same day. Within a week after the TOEIC test was conducted, the participants took all the memory tasks in the TOEIC class.

5. Results

5.1 Results for RQ 1

5.1.1 Descriptive Statistics

The descriptive statistics for all measures are presented in Table 1.

Table 1 ***Descriptive Statistics for All Measures***

	Mean	*SD*	*N*
TOEIC listening test	255.95	83.97	210
L1 LST	34.44	5.95	210
L2 LST	25.97	6.90	210
L1 DST	5.51	2.80	210
L2 DST	7.79	3.15	210

5.1.2 Correlation Analysis

The correlations among the memory variables and L2 listening comprehension are shown in Table 2. As seen in Table 2, the L1 measure of WM capacity yielded a significant correlation with L2 listening comprehension (r =.170, p<.05), but the relationship was weak. On the other hand, the L2 measure of WM capacity was significant but with a moderate correlation regarding L2 listening comprehension (r =.386, p <.05). STM measured by the L1 and L2 DST did not have a significant correlation with L2 listening comprehension. There was also a moderate correlation between the L2 LST and the L1 LST (r =.487, p <.001), and between the L2 DST and the L1 DST (r =.465, p <.001). The L1 LST correlated significantly with both the L1 DST (r =.154, p <.05) and the L2 DST (r =.243, p <.001), whereas the L2 LST correlated significantly with only the L2 DST (r=.224, p<.05). The relationship between WM capacity and STM capacity was expected, given that the LST included a storage demand, but was found to be weak.

Table 2 ***Correlations among LSTs, DSTs, and the TOEIC Listening Test (n=210)***

	(1)	(2)	(3)	(4)
(1) TOEIC listening test	---			
(2) L1 LST	.170*	---		
(3) L2 LST	.386**	.487**	---	
(4) L1 DST	.081	.154*	.091	---
(5) L2 DST	.123	.243**	.224**	.465**

*p <.05, **p <.01

5.1.3 Multiple Regression Analysis

To assess the influence of STM and WM capacity on L2 listening comprehension, a multiple regression analysis was performed with the TOEIC listening score as the dependent variables, and the memory variables as the independent variables. The results of the analysis using a stepwise regression analysis appear in Table 3. The value of the coefficient of determination (R^2) shows that L2 WM capacity accounted for 14.9 % of the variance in L2 listening comprehension. None of the other memory variables was predictive of L2 listening comprehension.

Table 3 ***Summary of Multiple Regression (n=210)***

Variables	ß	t	P	R	R^2	Adjusted R^2
L2 LST	.386	6.027	.000	.386	.149	.145

Note. F =36.326, p <.001

5.2 Results for RQ 2

5.2.1 Descriptive Statistics

To further investigate the relationship between L2 listening proficiency and the memory variables, the most proficient listeners and the least proficient listeners were compared. The top 30 participants who scored 355 and above in the TOEIC listening test were selected to be in the most proficient group, and the bottom 30 participants who scored 170 and below in the TOEIC listening test were selected to be in the least proficient group. Table 4 and Table 5 present the descriptive statistics for each group respectively.

Table 4 ***Descriptive Statistics for the Most Proficient Group***

	Mean	*SD*	*N*
TOEIC listening test	409.00	41.80	30
L1 LST	36.20	3.35	30
L2 LST	29.80	6.09	30
L1 DST	5.70	3.14	30
L2 DST	8.00	3.31	30

Table 5 ***Descriptive Statistics for the Least Proficient Group***

	Mean	*SD*	*N*
TOEIC listening test	149.00	22.95	30
L1 LST	32.77	7.88	30
L2 LST	21.97	8.10	30
L1 DST	4.60	2.79	30
L2 DST	6.73	3.42	30

5.2.2 Correlation Analysis

The correlations among the variables are shown in Table 6 for the most proficient group and Table 7 for the least proficient group, respectively. There were some marked differences between the two sets of correlations. Most notably, the correlation between L2 WM capacity and L2 listening comprehension in the most proficient group was greater than the corresponding correlation in the least proficient group.

Table 6 ***Correlations among the Variables for the Most Proficient Group (n=30)***

	(1)	(2)	(3)	(4)
(1) TOEIC listening test	---			
(2) L1 LST	.036	---		
(3) L2 LST	.437*	.487**	---	
(4) L1 DST	.209	.154*	.091	---
(5) L2 DST	.257	.243**	.224**	.465**

$^{*}p < .05$, $^{**}p < .01$

Table 7 ***Correlations among the Variables for the Least Proficient Group (n=30)***

	(1)	(2)	(3)	(4)
(1) TOEIC listening test	---			
(2) L1 LST	.466**	---		
(3) L2 LST	.288	.474**	---	
(4) L1 DST	.236	.203	.047	---
(5) L2 DST	.168	.321	.196	.726**

*p <.05, **p <.01

5.2.3 Multiple Regression Analysis

To assess the influence of STM capacity and WM capacity on L2 listening comprehension across proficiency levels, a multiple regression analysis was performed with the TOEIC listening score as the dependent variables, and the memory variables as the independent variables for each proficiency group. In the case of the most proficient group, the results of the analysis using a stepwise regression analysis appear in Table 8. The value of the coefficient of determination (R^2) shows that L2 WM capacity accounted for 19.1 % of the variance in L2 listening comprehension. On the other hand, none of the other memory variables was predictive of L2 listening comprehension. In the least proficient group, the results of the analysis using a stepwise regression analysis appear in Table 9. The value of the coefficient of determination (R^2) shows that L1 WM capacity accounted for 21.7 % of the variance in L2 listening comprehension. On the other hand, none of the other memory variables was predictive of L2 listening comprehension.

Table 8 ***Summary of Multiple Regression for the Most Proficient Group (n=30)***

Variables	ß	*t*	*p*	*R*	R^2	Adjusted R^2
L2 LST	.437	2.570	.016	.437	.191	.162

Note. F =36.326, p <.0.5

Table 9 ***Summary of Multiple Regression for the Least Proficient Group (n=30)***

Variables	ß	*t*	*p*	*R*	R^2	Adjusted R^2
L1 LST	.466	2.787	.009	.466	.217	.189

Note. F =7.77, p <.0.5

6. Discussion

The present study attempted to investigate whether individual difference in WM capacity and STM capacity influence L2 listening comprehension.

With regard to RQ 1, the correlational findings showed that only WM capacity was related to L2 listening comprehension. On the other hand, it was found that there were no significant correlations between L1 and L2 STM capacity, and L2 listening comprehension. This finding suggests that individual differences in STM do not predict variations in L2 listening comprehension. This interpretation is supported by the results of the regression analysis, which demonstrated that STM capacity accounted for no significant variance in L2 listening comprehension. On the other hand, L2 WM capacity accounted for a significant 14.5 % of the unique variance in L2 listening comprehension. The results that WM plays a greater role in L2 listening comprehension than STM are in line with the results of previous studies indicating the contribution of the variation in WM capacity to variation in L2 reading (Harrington & Sawyer, 1992; Waters & Caplan, 1996). Mental model building involved in listening processing includes the storage, reactivation, and timely integration of relevant prior representation, whereas STM involves the temporary storage of incoming information. It is assumed that the process of building a mental model may involve the attentional resource allocation aspect of the central executive in WM to a much larger extent than STM (Montgomery, Polunenko, & Marinellie, 2009).

With regard to RQ 2, the findings suggest that the limited capacity of WM may affect L2 listening comprehension for both advanced and elementary listeners. In the case of the most proficient listeners, L2 WM capacity accounted for a significant 16.2 % of the unique variance in L2 listening comprehension. This finding is consistent with studies of the relationship between L2 WM capacity and L2 reading comprehension with bilingual-level L2 users (Osaka & Osaka, 1992; Harrington & Sawyer, 1992). On the other hand, in cases of elementary listeners, L1 WM capacity accounted for a significant 18.9 % of the unique variance in L2 listening comprehension. This finding is also in tandem with Finardi and

Weissher's (2008) study of L2 speech production and development. The beginner-level listeners need to devote more cognitive resources to process what they hear in each phase of listening than advanced-level listeners. Given this, listeners' processing efficiency and the ability to control attention possibly affects L2 performance of the lower-level listeners. This might also be a reason why L1 WM capacity predicts L2 listening performance among the elementary listeners instead of L2 WM capacity. The L2 LST conducted in the present study might have failed to measure the controlled attention ability and the processing efficiency precisely enough, because their L2 linguistic knowledge and skills were not efficient enough. Therefore, the individual difference in the controlled attention component of WM capacity shared by L1 with L2 influenced the elementary listeners' L2 listening performance.

Another reason for this difference might be explained by the controlled attention theory of WM (Engle & Kane, 2004). According to this theory, there is a domain-general component of WM responsible for controlling attention as well as domain-specific components responsible for maintaining task-relevant information. The domain-general controlled attention ability is related to both higher-level cognition such as L2 comprehension and lower-level cognition requiring cognitive control (Colflesh & Conway, 2007). Colflesh et al. state that greater performance in WM tasks may reflect greater controlled attention and/or better use of domain-specific skills and strategies to aid maintenance. In the advanced-level group, it is quite likely that high-span individuals outperform low-span individuals in L2 listening comprehension because of the ability to use domain-specific knowledge effectively as well as the ability to control attention. Therefore, the individual differences in L2 LST performance of the advanced listeners may have reflected the differences in their personal experiences such as relevant background knowledge. On the other hand, in the elementary-level group, the high-span individuals are likely to outperform the low-span individuals in L2 listening comprehension because of the domain-general ability to control attention rather than the domain-specific knowledge, because their L2 linguistic knowledge and skills are limited. Using this line of argument, the individual difference in L1 LST performance of the elementary listeners may have reflected the difference in their ability to control attention.

7. Conclusion

The findings of the present study suggest that the limited capacity of WM could affect L2 listening comprehension with both advanced and beginner listeners. Previous studies of L2 reading have examined the relationship between WM capacity and L2 reading performance only with bilingual-level L2 users. The findings of the present study suggest that the limited capacity of WM could affect L2 listening comprehension not only when L2 linguistic knowledge and processing skills are automatic but also when such skills are not efficient (less automatic). The results highlight the role of the controlled attention component of WM in L2 listening performance in beginner-level L2 users. WM is thought to be related to both automatic and controlled processing. However, more importantly, the central executive control component of WM supports controlled processing and plays a greater role in attention controlled processing than automatic processing executed without conscious awareness (Engle, 2002; Ortega, 2009). To achieve effective teaching of L2 listening to lower-level listeners, developing language-related abilities will arguably contribute to saving the limited capacity of WM which is devoted to lower-level processing. If each of the lower-level processes become more automatic by improving lower-level skills such as L2 word recognition and L2 syntactic processing, the effect of WM capacity on L2 listening comprehension for beginner-level listeners will arguably be reduced. To conclude, more cognitive resources for lower-level listeners might be available for higher-level processing of L2 listening, once such lower-level skills are more automated.

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