The Effect of Working Memory on Component Processes of L2 Listening

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Abstract

The purpose of the present study is to investigate how working memory capacity influences the component processes of L2 listening. In Study 1, the relationship between working memory capacity and word recognition skills in the perceptional processing was examined. The result showed a significant difference between high-span and low-span listeners in the dictation test scores focusing on the phonological modification in the spoken discourse. Study 2 focused on the relationship between working memory capacity and the use of L2 cognitive and metacognitive listening strategies in the higher-level processing. The result suggested that high-span listeners in both higher-proficiency and lower-proficiency groups possibly use significantly more metacognitive strategies than low-span listeners in the same groups. These results derived from the two studies highlight a key role of working memory capacity in L2 listening processing regardless of proficiency levels of listeners.

1. Introduction

According to quite a few researchers (Berquist, 1998; Brigman & Cherry, 2002; Finaardi and Weissheimer, 2008; Fortkamp, 1999, 2003; Harrinton, 1992; Harrington and Sawyer, 1992; Miyake and Friedman, 1998), working memory capacity is considered to play an important role in the component processes involved not only in L1 but also L2 performance and development. More specifically, there has been found to be a positive correlation between working memory capacity and specific L2 skills, such as reading comprehension (Alptekin and Ercetin, 2010; Harrington and Sawyer, 1992), vocabulary acquisiton (Service and Kohonen, 1995), and syntax (Harrington and Sawyer, 1992; Miyake and Friedman, 1998). The study conducted by Satori (2010) also suggests the possible influence of working memory capacity on L2 listening development. However, despite the importance of working memory capacity, there is currently a limited understanding of the information processing and storage function of working memory capacity, especially in the listening process.

On the other hand, in the theoretical and empirical study of L2 listening instruction, Vandergrift (2004) concludes that the effective way of teaching L2 listening requires a balance between top-down, strategy-based approach and remedial, bottom-up training, because these two processes interact with each other to help listeners develop both real-life listening skills and word recognition skills. He proposes an integrated model for L2 listening instruction promoting metacognitive awareness and word recognition skills.

To achieve more effective teaching in L2 listening, it is a key to find out the effect of working memory capacity on these two types of processes stated above. Based on a finding that these two processes are in competition for limited capacity of working memory, and lower-level processing privileged at the expense of higher-level processing (Just & Carpenter, 1992; Zwaan & Brown, 1996), the present study aims at examining the relationship between working memory capacity and two constraints of L2 listening: metacognitive awareness of listening in higher-level top-down processes and word recognition skills in lower-level bottom-up processes.

2. Literature Review

2.1. A cognitive framework of listening comprehension processes

It is true that listening comprehension is not a passive activity but an active process in which the listener must discriminate between sounds, understand vocabulary and grammatical structures, interpret stress and intonation, and interpret it within the sociocultural context. Integrating all of this involves a great deal of mental activity on the part of the listener. Listening is a complex and difficult process, and deserves a great deal of attention and analysis (Vandergrift, 1999).

One possible view of comprehension is proposed by Anderson (1985). His three-phase model proposes that the process of comprehension consists of perception, parsing, and utilization. Perceptional processing in listening is the encoding of the acoustic signal. In this stage, listeners segment the continuous speech stream into phonemes and retain the aural input in the echoic memory. During parsing, the words recognized at the perceptional stage are converted into a mental representation of the combined message while an utterance is segmented with the help of syntactic structures and cues to meaning. During utilization, this mental representation is related to existing knowledge and stored in long-term memory as propositions.

As stated above, lower-level bottom-up processing is mainly employed during the perception and parsing stage of aural comprehension. Higher-level top-down processing is employed during the utilization stage.

2.2. Problems related to different stages of listening comprehension

Based on the process approach stated above, Goh (2000) identified 10 processing problems that occurred during the perception, parsing, and utilization stage from a group of ESL learners' self-reports. Among the 10 problems, 5 were perceptual problems linked to word recognition and attention failure. Parsing problems were linked to the difficulty with retaining what is heard and forming a mental representation of the words. The problems reported in the utilization stage included the difficulty with understanding the intended message and the main idea in it because of a lack of prior knowledge or its inadequate application.

2.3. A cognitive perspective on strategy uses in L2 listening comprehension

To provide the evidence in support of the three cognitive processes proposed by Anderson (1985) in L2 listening comprehension, O'Malley, Chamot, and Kupper (1989) used think-aloud protocols and examined the strategies used by ESL learners during each phase of the listening process. Statistical analysis of strategy use revealed the differences between effective and ineffective listeners. Moreover, qualitative analysis of transcripts showed that listeners used different strategies on each phase of the listening process. For example, selective attention proved to be crucial during the first phase, perceptional processing. Effective listeners were more aware of their attention failure and redirected their attention to the oral text more effectively than ineffective listeners. During the second phase, parsing processing, grouping and inference from context proved to be important. By using both top-down and bottom-up processing, effective listeners focused on larger chunks than ineffective listeners and inferred the meaning of the unknown words from context. On the other hand, ineffective listeners used only bottom-up processing to try to segment the spoken discourse on a word-by-word basis. In the utilization phase, effective listeners reported utilizing elaboration from world knowledge, personal experience, or self-questioning. Such elaborations also proved to be useful for supporting inference based on the background knowledge.

2.4. The importance of raising metacognitive awareness of listening

Based on cognitive theory, O'Malley and Chamot (1990) categorized language learning strategies into two main types: metacognitive and cognitive strategies. Metacognitive strategies including planning, monitoring, and evaluation are important, because they direct the language learning process. On the other hand, cognitive strategies apply a specific tactic (Goh, 2000) to the task, and enhance the potential of the metacognitive strategies (Vandergrift, 1999).

Some researchers have focused on the difference in strategy use between effective and ineffective listeners. Rost and Ross (1991) observed the correlation between the choice of strategy and the proficiency of the listeners based on the analysis of native speaker-non-native speaker discourse. This study observed 8 strategies and identified four of them as related to language proficiency and discriminating between "high" and "low" proficiency learners. Vandergrift (2003) also examined the types of strategies and the differences in strategy use by more skilled and less-skilled listeners, and concluded that more-skilled learners used more metacognitive listening strategies than less-skilled listeners did. Other researchers also point out the importance of the effective use of metacognitive strategies for successful listening comprehension (Hasan, 2000; Mareschal, 2002). Moreover, successful listeners are reported to combine metacognitive and cognitive strategies effectively (Goh, 2002; Mareschal, 2002).

2.5. The importance of developing word recognition skills for more automatic processing

As pointed out by Vandergrift (2004), the approach to listening instruction is likely to change from a focus on the product of listening to a focus on the process. He claims the importance of developing both word recognition skills in bottom-up processing as well as matecognitive awareness in top-down processing.

Many researchers also suggest the importance of bottom-up skills in listening comprehension (Buck, 2001; Rost, 2002; Field, 2003; Wilson, 2003). Less-skilled or lower-level listeners lack automatic linguistic decoding skills, therefore, they initially need plenty of contextual support to compensate for the gap in understanding (Goh, 2002; Segalowitz & Segalowitz, 1993). Tsui and Fullilove (1998) state less-skilled listeners need to rely more on rapid and accurate decoding of the linguistic input, and less on guessing from contextual or prior knowledge.

Vandergrift (2004) states that automatic word recognition skills are possibly the most crucial parts of bottom-up skills for successful listening comprehension. Hulstijn (2001) also suggests that the development of bottom-up skills is adequate for all the components of acoustic signal to become meaningful units for the listener.

Segalowitz (2005) defines the automacity as fast, ballistic, holistic, and implicit processing which requires less cognitive resources. To conclude, more cognitive resources are available for comprehension, which is a higher-level processing in listening, once bottom-up skills are automatized.

2.6. The capacity theory of working memory

According to Just and Carpenter's theory (1992), working memory capacity constrains comprehension and the total amount of activation-mediating processing and storage varies among individuals in reading comprehension. Current models for L2 comprehension accept a trade-off between storage and processing functions of working memory (Miyake, Just & Carpenter, 1994). In L2 listening, the listeners are forced to devote more cognitive resources to lower-level processing, because they have limited L2 linguistic knowledge. Vandergrift (2004) claims that listeners with more automated processing have more room in working memory to retain more information and revise the prior information as they listen.

2.7. Working memory capacity and L2 performance

Some researchers claim that working memory capacity is possibly an independent constraint on second language acquisition. They state that working memory capacity plays a greater role in L2 acquisition by adult learners than in L1 acquisition because of the less automatic nature of L2 procedures (Berquist, 1998; Fortkamp, 1999, 2003; Harrinton, 1992; Harrington and Sawyer, 1992; Miyake and Friesman, 1998; Mizera, 2006).

Harrington and Sawyer (1992) found a significant correlation between participants' reading span scores (an active working memory capacity task) in L2 and their performance in Grammar and Reading sections of the TOEFL test. They incorporated a grammaticality judgment task in their reading span test, whereby the participants were asked to judge whether the target sentence was grammatical or ungrammatical both syntactically and semantically. Ortega (2009) argues that the task, administered in the participants' L2, relied heavily on L2 reading skills. On the other hand, Juffs (2004) investigated individual differences in online processing of ambiguous L2 sentences by using the same type of reading span test as Harrington and Sawyer (1992), and showed that the role of working memory in such L2 performance was extremely weak. A more recent study (Shiotsu, 2010) to address components of L2 reading also showed only a weak correlation (r=.15, p<.05) between working memory as measured through Osaka and Osaka's (1992) L2 Reading Span Test (RST) and reading comprehension ability. Daneman and Merikle's (1996) meta-analysis of 77 relevant studies concerning WM shows that the average correlation between RST (Daneman & Carpenter, 1980) and reading comprehension is r = .41 (with a 95% confidence interval of .38 to .04).

As Shiotsu (2010) suggests, performance on the working memory task may depend on the extent to which the task requires limited cognitive resources. Therefore, further investigation on the measure of working memory would be necessary before concluding the role of working memory in L2 performance.

3. Research Questions

The report in this article is part of a larger study on the effect of working memory capacity on L2 listening component processing. Ortega (2009) states that 'research on the relationship between memory and differential L2 achievement has only begun to scratch the surface'(p158), little is known about how working memory facilitate differential rate and success of L2 achievement. The present study aims to test the possibility that working memory capacity plays a role in L2 listening processing by examining the relationship between a measure of active working memory capacity and two measures of L2 performance in both bottom-up and top-down processing. The research questions addressed in each study were:

(1) Does working memory capacity influence word recognition skills in L2 listening ?
(Study 1)

(2) Does working memory capacity influence listening strategy use in L2 listening ?
(Study 2)

4. Study 1

4.1. Participants

Participants in this study were 70 1st and 2nd year English language major Japanese students aged between 18 and 24 from a technical college in Japan. Their level of English proficiency, measured by the TOEIC test, ranged from scores of 200 to 930 (The average of their TOEIC test scores = 438.21, *SD* =177.92). Before participating in the research, the participants were asked to read and sign a consent form.

4.2. Instruments

4.2.1. 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.

4.2.2. Dictation test

For this study, based on the finding that phonetic features in natural speech by English native speakers affect the performance of word recognition in perceptional processing by native speakers (Buck, 2001; Field, 2003; Lynch, 1998), a partial dictation test (Fujita, 2003) was administered as an indicator of word recognition skills. It consisted of 7 parts, each included 20 segments, and focused on phonetic features: reduction, contraction, liaison, elision, deletion, assimilation, and coalescence assimilation. The words related to each sound change were deleted from 20 dictation segments. The total number of eliminated words was 260. The subjects listened to the entire segment only once and they were given 10 seconds after listening to each segment to fill in the deleted portion in the blanks on their test paper. The dictation test responses were scored on the exact word scoring basis. However, legible spelling errors were counted as correct.

4.2.3. The Japanese version of Reading Span Test (RST)

As Osaka and Osaka (1992) suggest, working memory is language independent, and the learners' low proficiency might affect the performance of the task. More recent L2 research has employed L1 active measures of working memory capacity that capitalize on the idea of trade-off between storing and processing (Sagarra, 2008). Therefore, the Japanese version of RST (Osaka, 2002), modified for group testing with a large number of participants (Ushiro and Sakuma, 2000) was employed in this study. The test was administrated to the participants by using a power point presentation and screen in a computer room.

The procedure for conducting the RST in this study was as follows. Five sets of sentences were presented in each sentence condition ranging from two to five. Each sentence was presented on the screen and the subjects were required to read the sentence aloud with the same speed as the examiner and write down the underlined words in the sentence at the end of each set. There was no pause between the sentences. No break was permitted in the experiment. The time to recall the target word was 5 seconds per sentence, which is 10 seconds in the 2-sentence condition, and 20 seconds in the 4-sentence condition.

Scoring was conducted based on the method adopted by Daneman and Carpenter (1980). The subjects were regarded as having cleared each sentence condition when they recalled 3 or more sets out of five in each condition and they were scored 0.5 when they recalled only two sets out of five, and 0 when they recalled only one set or none out of five.

4.2.4. Procedure

The study was conducted in the first semester of 2009. The TOEIC test was administered to the participants on the same day. Within a week after the TOEIC was conducted, the participants took dictation tests and the Japanese version of RST in their TOEIC classes, which were divided into two lessons to reduce their burden of tiredness.

4.3. Results of study 1

4.3.1. Correlation with working memory capacity

First, in order to examine the relationship between working memory capacity and the two listening test scores, a correlation was performed. The descriptive statistics of the measures and the correlation between the two listening tests scores and the RST scores are shown in Table 1 and Table 2 respectively. As can be seen in column 1 of Table 2, the RST scores were found to have little relationships with the two listening tests.

Table 1. Descriptive Statistics: RST, TOEIC listening and Dictation (N=70)

	Mean	SD
RST scores	3.30	0.99
TOEIC listening test scores	257.14	93.46
Dictation test scores	149.70	47.69

Table 2. Correlation between RST score, and two listening tests scores (N=70)

	RST	TOEIC	Dictation
RST scores	-	.157	.197
TOEIC listening test scores	.157	-	.868**
Dictation test scores	.197	.868**	-

**$p<.01$

4.3.2. Analysis by working memory and word recognition skills according to Group

Because no statistically significant correlations were found in the analysis discussed in 4.3.1, a second set of analyses were performed by grouping participants according to their performance on the RST. The participants who scored 3 and below in the reading span were regarded as the low-span group, and those who scored 3.5 and above were regarded as the high-span group. The descriptive statistics for the mean scores of the dictation tests as an indicator of word recognition skills for each group are shown in Table 3.

The results of the t-test analysis confirmed a significant difference in the dictation mean scores between the high-span group and the low-span group (t=2.307, p<.005). The difference also presented a medium sized effect (d=.55).

Table 3. Descriptive Statistics for the Dictation Mean Scores

Group	N	Mean	SD
High-span group	35	162.457	49.680
Low-span group	35	136.943	41.107

The descriptive statistics for the mean scores of the TOEIC listening tests as an indicator of listening comprehension for each group are shown in Table 4.

A t-test analysis was conducted to confirm the difference of the TOEIC listening mean scores between the high-span and low-span groups. The t figure itself did not reach the critical level of .05, though it was close critical value (t=1.861, p=.067). The effect size of the difference (d=.45) in TOEIC listening test scores is smaller than that in dictation test scores (d=.55). These findings imply that working memory capacity contributed to L2 word recognition skills more than L2 listening proficiency as a whole.

Table 4. Descriptive Statistics for the TOEIC Listening Test Mean Scores

Group	N	Mean	SD
High-span group	35	277.571	101.294
Low-span group	35	236.714	78.266

5. Study 2

5.1. Participants

Participants in this study were 90 1st and 2nd year English language major Japanese students aged between 19 and 23 from a technical college in Japan. Their level of English proficiency, measured by the TOEIC test, ranged from scores of 225 to 900 (The average of their TOEIC scores =528.12 , SD =139.53). Before participating in the research, the participants were asked to read and sign a consent form.

5.2. Instruments

5.2.1. Listening comprehension test and strategy questionnaire

In this study, the listening section of the TOEIC test was taken by the participants as a measurement of L2 listening comprehension. Soon after the TOEIC listening test, listening strategy use was measured through a questionnaire which consisted of 17 statements related to 5 metacognitive strategies and 12 cognitive strategies, adapted for listening by Vandergrift (1997) from O'Malley and Chamot (1990). The questionnaire was translated into Japanese to make sure it could be easily understood by the participants (See Appendix). The participants were required to rate on the frequency of their strategy use through a three point scale, the degree to which they deployed each of the strategies in the TOEIC listening test.

5.2.2. The Japanese version of RST

In this study, the same measure of the Japanese version of RST as in Study 1 was administered. The procedure was also conducted in the same way as Study 1 by using a power point presentation and screen in a computer room. Scoring was also conducted based on the same method as Study 1.

5.2.3. Procedure

The study was conducted in January 2010. The TOEIC test and the listening strategy questionnaire were administered to the participants on the same day. Two days after, the participants took the Japanese version of RST.

5.3. Results of study 2

5.3.1. Correlation with working memory capacity

First, in order to examine the relationship between working memory capacity and listening strategy use, a correlation of analysis was performed between Reading span scores and listening strategy use. The descriptive statistics and the correlation are shown in Table 5 and Table 6 respectively.

Table 5. Descriptive Statistics: RST, TOEIC listening, and strategy use (N=90)

	Mean	SD
RST scores	3.28	.97
TOEIC listening scores	320.67	70.70
Metacognitive Total	10.97	2.00
Cognitive Total	23.72	4.30

As shown in Table 6, metacongnitive strategy use was found to have a statistically significant correlation to RST scores and TOEIC listening test scores, though the size of the correlation are interpreted as small or medium. On the other hand, no statistically significant correlations were found between cognitive strategy use and the two listening test scores.

Table 6. Correlations between RST scores and TOEIC listening scores

	RST scores	TOEIC listening test scores
Metacognitive Total	.331**	.363**
Cognitive Total	.118	.201

**$p<.01$

5.3.2. The analysis by working memory

In order to examine the effect of listening proficiency and working memory capacity on L2 listening strategy use, the participants were divided into 4 groups based on their performance on the TOEIC listening test and the RST. The participants who scored below average in the TOEIC listening test were regarded as the lower-level group, and those who scored above were regarded as the upper-level group. Moreover, the participants who scored 3 and below in the Japanese version of RST were regarded as the low-span group, and those who scored 3.5 and above were regarded as the high-span group. The descriptive statistics for the mean frequency of strategy use are shown in Table 7.

Table 7. Mean frequency of strategy use

	Upper-level		Lower-level	
Strategy	High-span	Low-span	High-span	Low-span
Metacognitive Total	12.364	10.478	11.000	10.087
Cognitive Total	24.500	22.435	24.318	23.696

To test for significant differences between the means for upper-level, lower-level, high-span and low-span listeners for metacognitive and cognitive strategy use, an analysis of variance (ANOVA) was conducted as shown in Table 8.

Table 8. ANOVA summary results for strategy use differences

Strategy	F (Proficiency)	F (Working memory)	F (P×W)
Metacognitive total	5.123*	13.027****	1.573
Cognitive total	0.335	2.201	0.634

*$p<.05$, ****$p<.00001$

As shown in Table 8, higher-level and high-span listeners were found to use significantly more metacognitive strategies than lower-level and low-span listeners. The result showed no significant interaction between proficiency and working memory capacity. In other words, the main effect of each variable was not found to be affected by the other.

6. Discussion

The first finding in the present study was that the difference in working memory capacity was related to word recognition skills in bottom-up processes in L2 listening. Because of limited language knowledge, L2 listeners, especially lower-level listeners can process little of what they hear automatically. As a result, they need to pay more attention to individual words and devote the limited cognitive resources to lower-level processing. High-span listeners, with more working memory capacity, retain more information than low-span listeners and revise prior information as they listen. As a result, high-span listeners showed significantly greater performance in L2 word recognition, which requires both linguistic knowledge such as phonological modification knowledge and working memory.

Another finding in Study 2 is that high-span listeners possibly use significantly more metacognitive strategies than the low-span listeners. Using strategies such as selective attention while listening possibly requires attention resources limited in working memory. Therefore, high-span listeners with more working memory capacity can allocate more cognitive resources in the execution of metacognitive strategies required in higher-level processing than low-span listeners. Upper-level listeners with more automatized bottom-up skills also use significantly more metacognitive strategies than lower-level listeners. One possible explanation is that upper-level listeners have more working memory capacity because of more automatized bottom-up skills, thus, freeing up working memory resources to be allocated to the execution of metacognitive strategies in higher-level processing rather than lower-level processing.

7. Conclusion

Before concluding, the limitation of this study has to be pointed out. Firstly, in study 2, a self-report measure was used, not a direct test. Generally, whether the scores on the questionnaire represent a reasonably accurate reflection of the construct or not, is sometimes disputable, therefore, the results should be interrupted cautiously. Secondly, in future research, two measures of working memory capacity should be used, one in L1, and another in L2, because working memory scores in L1 and L2 may be independently motivated to some extent, as stated by Kyria and Weissheimer (2008). Moreover, in the comparison of four common methods for scoring a reading span tests, Friedman and Miyake (2005) pointed out the reliability of more continuous measures focusing on the total number of words rather than traditional span scores focusing on the number of words in correct sets. These issues should be addressed in future research. Despite these limitations, the results of this study could be taken as a first step into the exploration of how working memory capacity is related to L2 listening component processes.

The difference in L2 listening skills and strategies use between high-span and low-level listeners found in this study is understood to reflect some impact of working memory on both higher-level and lower-level processing in L2 listening.

Working memory capacity is assumed to play a greater role in controlled processes than automatic processes executed without awareness. If each of the component processes in L2 listening gets more automatic as a result of increased linguistic knowledge and strategies use through practice, the effect of working memory capacity on L2 performance possibly gets less. In other words, beginner-intermediate level listeners need to devote more cognitive resources to process what they hear in each phase of listening than advanced-level listeners. In that case, working memory capacity related to the listeners' processing efficiency affect the L2 performance of the lower-level listeners more than higher-level listeners. For further research, the influence of working memory capacity on other linguistic knowledge and processing skills as components of L2 listening needs to be explored.

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Appendix: Strategy use questionnaire

今日実施されたTOEICのリスニングテストで次のストラテジーをどの程度使いましたか？

1．使わなかった　　2. 少し使った　　3. よく使った

Metacognitive strategies

Strategy	内容	1	2	3
Advance organization	リスニングの目的や課題内容をはっきりとさせる			
Directed attention	前もってリスニングに集中する心構えをする			
Selective sttention	理解の手助けになる特定の音声や情報に意識を傾ける			
Self-mannagement	リスニング課題達成のための条件を確認し、整えようとする			
Comprehension monitoring	自分が理解しているかどうかを、その場で確認する			

Cognitive strategies

Strategy	内容	1	2	3
Linguistic inferencing	知らない単語を他の単語から推測する			
Voice inferencing	知らない単語を声のトーンから推測する			
Extralinguistic inferencing	背景の声や人物関係などから状況を推測する			
Between-parts inferencing	行間から状況を推測する			
Personal elaboration	個人的経験に照らし合わせる			
World elaboration	一般的な常識に照らし合わせる			
Question elaboration	様々な関連する事柄について自問し、一般常識から答えを出す			
Imagery	絵や場面などを想像する			
Summarization	まとめをしてみる			
Translation	日本語に訳してみる			
Transfer	日本語の知識を生かす			
Repetition	聞いたものをリピートする			

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