What Relationships Do the Efficiency of Phonological Coding and Working Memory Capacity Have with Reading Comprehension for Japanese Learners of English?

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This article investigated into differences between first- and third-year senior high school students concerning: (a) the efficiencies of phonological coding and working memory capacities; and (b) the relationships of these two variables with reading comprehension. Also explored was whether the relationships were reflected in word-retaining strategies of the first-year students in the reading span tests for measuring working memory capacities. The findings were: (a) students may improve their working memory capacities but may not improve the efficiencies of phonological coding during the first two years of senior high school; (b) the efficiency of phonological coding contributes to reading comprehension more greatly for first-year students, but working memory capacity contributes to reading comprehension for third-year students; and (c) the word-retaining strategies of first-year students reflect the relationships between the two variables and reading comprehension. The reasons for these findings were discussed and pedagogical implications were shown.

Key Words : phonological coding, working memory capacity, reading comprehension

音韻符号化効率及び作動記憶容量と読解力の関係
－日本人高校生の場合－

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本論は, (a) 音韻符号化効率と作動記憶容量, (b) この2要因と読解力の関係, に関して, 高校1年生と3年生の違いを調査した。また, 作動記憶容量測定リーディングスパンテストにおける1年生の語維持方略にこの関係が反映されるか調査した。その結果, (a) 高校生は最初の2年間に, 作動記憶容量が増大する可能性があるが, 音韻符号化効率は高まらない可能性がある, (b) 音韻符号化効率による読解力への影響は1年生の方が強いが, 3年生では作動記憶容量による読解力への影響がある, (c) 1年生の語維持方略に, 2要因と読解力の関係が反映される, 等が示された。この結果をもたらした原因に関する考察及び, 教育的示唆が示された。

キーワード：音韻符号化, 作動記憶容量, 読解力

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1. INTRODUCTION

In spite of the recent fad of oral reading in English language teaching (ELT) in Japan, attempts to improve learners' reading comprehension and English proficiency through oral reading practice have been in just a fledgling stage. Nevertheless, the following assumptions have been made about the functions of oral reading practice: (a) it raises grammatical consciousness; (b) it expands vocabulary; (c) it strengthens letter-sound association; and (d) it improves the efficiency of working memory (Miyasako, in press, Miyasako & Takatsuka, 2004).

First, grammatical consciousness raising, which aims at developing explicit grammatical knowledge (Ellis, 1997), should naturally take place in oral reading for most Japanese learners of English who are half-obsessed with grammar. They may notice some grammatical gaps in their interlanguages when reading comprehensible passages aloud and restructure them, as SLA research shows (Ellis, 1997, Schumidt, 2001, Skehan, 1998).

Second, learners can acquire new words and phrases that they encounter more frequently than necessary for acquisition, 5 to 16 times (Nation, 1990), in reading comprehensible passages aloud.

Third, learners' letter-sound association can be strengthened by oral reading practice, which improves the efficiency of phonological coding, i.e., converting written information into phonological information, in the phonological loop of working memory (Gathercole & Baddeley, 1993). This is empirically supported by studies showing that oral reading practice improved the efficiency of phonological coding in terms of oral reading speed for senior high school students (Miyasako, 2002, Suzuki, 1998, Watanabe, 1990).

Fourth, working memory defined in the capacity theory[1] is a working space to process and store activated information simultaneously (Just & Carpenter, 1992), which roughly corresponds to the central executive and episodic buffer in Baddeley's (2000) model. Since more cognitively loaded tasks are likely to activate working memory more greatly (Osaka, et al., 1999, Osaka, 2002), oral reading practice, which is a complex and cognitively demanding activity dealing with comprehension and oral production of the passage simultaneously, may be able to improve the efficiency of working memory in terms of its processing capacity. Thus, it can be hypothesized that oral reading practice will contribute, directly or indirectly, to the improvement of reading comprehension and English proficiency.

So far, findings relevant to oral reading for Japanese senior high school students (Miyasako, 2002, 2003, 2004, in press, Miyasako & Takatsuka, 2004) seem to confirm: (a) oral reading ability[2] predicts English proficiency; (b) the metacognition of oral reading predicts English language ability[3] and oral reading ability; (c) oral reading practice makes a favorable change in the metacognition of oral reading; (d) oral reading practice improves English language ability and changes the metacognition of oral reading more greatly for learners with lower English language ability than for learners with higher English language ability; (e) the efficiency of phonological coding predicts reading comprehension; and (f) working memory capacity predicts reading comprehension.

Since the present study focuses on points germane to the findings (e) and (f), they are reviewed here in a little more detail. Miyasako & Takatsuka (2004) showed, in a study with 48 second-year senior high school students, that the efficiency of phonological coding as measured by English articulation speed explained 19.2% of the variance of reading comprehension. Miyasako (2004) revealed that working memory capacity as measured by the ESL version of reading span test (Osaka & Osaka, 1994) had a significant correlation with reading comprehension for third-year senior high school students ($r=.451$, $p<.05$, $n=24$), confirming the relationship between the two variables for ESL learners (Daneman & Merikle, 1996) and for higher proficiency Japanese EFL learners (Kato, 2003).

These two studies validated the roles of working memory in Baddeley's terms, i.e., phonological loop for phonological coding and central executive plus episodic buffer corresponding to working memory defined in the capacity theory, in reading comprehension for senior high school students. The importance of phonological coding in decoding has been acknowledged in L1 reading research (Grabe, 1999, Nicholson, 1999, Snow, et al., 1998, Stanovich, 2000). Baddeley (2000) even came to regard phonological loop as a key phonological language learning device. Working memory where syntactic parsing and comprehension as well as decoding of information take place is indispensable for the reading process (Grabe & Stroller, 2002, Stanovich, 2000).

However, it has not been known whether the efficiencies of phonological coding and working memory capacities of Japanese senior high school students improve as their chronological ages and length of English learning increase. Our speculation concerning this question was that students would improve the efficiencies of phonological coding and working memory capacities in accordance with their maturity and length of English learning, based on the following relevant research findings: (a) both fluent and poor readers depend on the bottom-up processing to understand the text (Nicholson, 1999, Snow, et al., 1998, Stanovich, 2000); (b) decoding ability is related with reading comprehension for adults as well as children (Stanovich, 2000); (c) the teaching of decoding skills has significantly favorable effects on the development of reading comprehension skills for young learners (Castle, 1999, Grabe & Stroller, 2002, Snow, et al., 1998); and (d) adolescents are still at developing stages of their working memory capacities (Siegel, 1994).

Therefore, we examined the above-mentioned speculation by investigating into the efficiencies of phonological coding and working memory capacities for first- and third-year senior high school students, and the relationships of these two variables with reading comprehension among the first- and third-year students. We also analyzed strategies that the first-year students used for retaining words in the reading span tests for measuring working memory capacity, which might reflect their phonological or lexical processing of words in the reading process (Osaka & Nishizaki, 2000).

For these investigations and analyses the following research questions were addressed: (1) are there any differences in the efficiencies of phonological coding and working memory capacities between first- and third-year senior high school students?; (2) are there any differences in the relationships of the efficiencies of phonological coding and working memory capacities with reading comprehension between first- and third-year senior high school students?; and (3) are the relationships of the efficiencies of phonological coding and working memory capacities with reading comprehension reflected in the word-retaining strategies of first-year students?

2. METHOD

2.1. Participants

This experiment was conducted in June of 2003. The participants were 136 senior high school students, composed of 40 first- and 72 third-year students plus 24 third-year students in Miyasako (2004). These students were named first-year group and third-year groups A and B respectively. All the participants belonged to the same school and the third-year groups A and B were at the same level of English reading comprehension as measured by *Assessment of Communicative English*[4] (ELPA) (Mann-Whitney U= 785.500, ns, Tables 5 and 6). The participants' English proficiencies were judged to be in the range of elementary to intermediate levels after their studying English as a foreign language for over three to five years. Reading comprehension as measured by *Basic Assessment of Communicative English*[4] (ELPA) showed a significant difference between the first- and third-year students (Mann-Whitney U=516.500, p<.01, Tables 3, 5 and 6).

2.2. Materials

Reading Comprehension. We adopted two assessments of reading comprehension, i.e., the reading sections of the past versions of *Assessment of Communicative English* and *Basic Assessment of Communicative English* (ACE and BACE). The more difficult ACE (20 items in 30 minutes) is designed mainly for second- and third-year students, and the less difficult BACE (12 items in 20 minutes) mainly for first-year students. These two tests, developed based on the Item Response Theory as are TOEFL and TOEIC, are considered as valid measures of English proficiency[5]. ACE was used for the third-year groups A and B and BACE for all the groups.

Efficiency of Phonological Coding. The efficiency of phonological coding was measured with an English word articulation test (EAT). In the test, the numbers of syllables articulated in two seconds, which is about the maximum duration when phonological information is stored in the phonological loop without subvocal rehearsal (Baddeley, et al., 1998), were gauged. The first-year group and third-year group A read aloud 40 familiar English words consisting of 114 syllables as fast as possible (Appendix A). The reason for using familiar words instead of pseudowords for the test, both of which are considered valid measures of word attack, i.e., phonological coding (Quiroga, et al., 2002, Stage, et al., 2001), lay in the difficulties in our controlling the participants' hesitation and guessing time in naming unknown words and in our judging the correctness of their word naming.

Formula for their English articulation speeds (ASs) was as follows: English AS=114 (syllables in 40 words) x 2.0 / time for articulating 40 words (sec.).

Working Memory Capacity. Three reading span tests[6] (RSTs) (Daneman & Carpenter, 1980) were adopted for measuring working memory capacities of the first-year group and third-year group B. For the first-year group, we developed a RST for lower English proficiency senior high school students (L-RST) by using 6- and 7-word sentences mainly taken from authorized course books for junior high school students (Appendix B). The L-RST consisted of three sets of two to six incremental sentences, 60 sentences in total. The participants' reading spans were scored as the maximum numbers of sentences whose final words they could perfectly recall in two out of three sets. The test observed the standard procedure of the RST[7].

The second RST that we used for the first-year group was the Japanese version of RST (J-RST) (Osaka & Osaka, 1994). This was mainly used to examine the reliability of the L-RST. The procedure for conducting and scoring the test followed the L-RST.

The third one for the third-year group B was the ESL version of RST (ESL-RST), designed for measuring the working memory capacities of Japanese college students, which showed a significant reliability with the RST, CMU (Carnegie-Mellon University) version, $r=.75$, $p<.01$ (Osaka & Osaka, 1994, Osaka, 1998). We gave this ESL-RST minor modifications in several sentences so that the participants would not have trouble understanding them. This test observed the standard procedure of the RST.

Word-retaining Strategies. We interviewed the first-year group individually to identify strategies that they used to retain final words in the L-RST and J-RST immediately after the tests. Word-retaining strategies were categorized into three elaborate strategies, i.e., imaging, sentence-making and translation, and non-elaborate strategies, i.e., rehearsal and no-strategy, based on Osaka & Nishizaki (2000). When the participants used "imaging", they tried to image something with words. With "sentence-making" they tried to make sentences with words. In using "translation", they tried to translate words into Japanese. In "rehearsal", they tried to repeat words subvocally.

2.3. Procedure

First, the first-year group (n=40) took the EAT for the efficiency of phonological coding and BACE for reading comprehension in this order in a regular 65-minute class. They also took the L-RST and J-RST for working memory capacity and the interview about their word-retaining strategies individually after school. Second, the third-year group A (n=72) took the EAT and two reading comprehension tests, i.e., ACE and BACE. These three tests were separately administered in regular classes. Third, the third-year group B (n=24) took the ACE and BACE separately in regular classes and the ESL-RST individually after school (Miyasako, 2004). In all of the EATs, the participants measured their articulating times with stopwatches by themselves.

3. RESULTS

3.1. Efficiency of Phonological Coding

Table 1 shows the descriptive statistics of the EATs for measuring the efficiencies of phonological coding of the first-year group and third-year group A. The mean values were about the same between the two groups (first-year=8.081, third-year A=8.106), which was statistically supported by the one-way factorial ANOVA [$F(1, 110) =.006$, ns]. It seems that the third-year students have made hardly any progress in the efficiencies of phonological coding during the first two years of studying English.

3.2. Working Memory Capacity

Table 2 shows the descriptive statistics of the L-RST and ESL-RST for working memory capacities of the first-year group and third-year group B respectively. First, the maximum values for the first- and third-year groups were 3 and 5 respectively. In the first-year group there were no students with high working memory capacities, over 4 in the reading span (Daneman & Carpenter, 1980). Second, the mean value was larger in the third-year group B than in the first-year group (first-year=2.075, third-year B=2.500). The one-way factorial ANOVA revealed that there was a significant difference in the means between the two groups [$F(1, 62) =5.125$, $p<.05$]. It seems that the third-year students have significantly improved their working memory capacities during the first two years of studying English.

3.3. Relationships between the Variables for First-year Group

Tables 3 and 4 show the means of the EAT, BACE, L-RST and J-RST and the correlations between them for the first-year group. The EAT had a significant correlation with the BACE ($r=.655$, $p<.01$), suggesting a significant role of phonological coding in reading comprehension. This was validated by the regression analysis showing that the efficiency of phonological coding could explain 42.9% of the reading comprehension variance [$\beta=.792$, $t=5.146$, $p<.01$; $F(3, 36)=9.930$, $R^2=.453$, $p<.01$] (Table 5).

In contrast, the L-RST had no significant correlation with the BACE, which did not comply with the relationship shown in a meta-study ($r=.41$, $p<.05$) (Daneman & Merikle, 1996). The L-RST had no significant correlation with the EAT as well. It seems that working memory capacity was not effectively used for higher level processing than decoding, such as parsing, proposition formation and comprehension, for the first-year group.

Another significant correlation existed between the L-RST

Table 1. Descriptive Statistics of EAT for First-year Group and Third-year Group A

Group	n	Mean	SD	Max.	Min.
First	40	8.081	1.819	12.019	4.335
Third-A	72	8.106	1.656	11.753	4.692

Table 2. Descriptive Statistics of RSTs† for First-year Group and Third-year Group B

Group	n	Mean	SD	Max.	Min.
First	40	2.075	.616	3	1
Third-B	24	2.500	.885	5	1

† RSTs for the first- and third-year groups were the L-RST and ESL-RST respectively.

Table 3. Means of Variables for First-year Group

	n	Mean	SD
EAT	40	8.081	1.819
BACE	40	6.925	2.235
L-RST	40	2.075	.616
J-RST	40	2.350	.622

Table 4. Correlation Matrix for First-year Group

	EAT	BACE	L-RST	J-RST
EAT	-			
BACE	.655**	-		
L-RST	.088	.209	-	
J-RST	.175	.167	.465**	-

**p<.01, n=40.

Table 5. Regression Analysis on BACE with EAT, L-RST and J-RST

	β	t-value	p-value	R^2
EAT	.792	5.148	<.001	.429
L-RST	.589	1.164	.2521	-
J-RST	-.076	-.150	.8813	-

$Y=-.518+.792X_1+.589X_2-.076X_3$; $R_2=.453$; $F(3, 36)=9.930$, $p<.01$.

and J-RST (r=.465, p<.01) but the coefficient was smaller than a favorable value, r>.700, for showing the reliability of the L-RST.

3.4. Relationships between the Variables for Third-year Groups A and B

Table 6 shows the means of the EAT, ACE and BACE and the correlations between them for the third-year group A. The EAT had a significant correlation with the ACE (r=.273, p<.05) but no significant correlation with the BACE. This result suggested a ceiling effect of the BACE. This test, designed for first-year students, may have been easy for third-year students with inefficient phonological coding. Similarly, another significant but moderate correlation between the ACE and BACE (r=.515, p<.01) indicated the possibility of the ceiling effect of the BACE.

Table 7 shows the means of the ESL-RST, ACE and BACE and the correlations between them for the third-year group B. The ESL-RST had a significant correlation with the ACE (r=.451, p<.05) but no correlation with the BACE. The former was valid, comparable to the result of a meta-study concerning the relationship between working memory capacity and global reading comprehension, with the mean coefficient being .41, p<.05 (Daneman & Merikle, 1996). The latter suggested the ceiling effect of the BACE as in the third-year group A. Another significant correlation between the ACE and BACE (r=.491, p<.05) was close to that for the third-year group A (r=.515, p<.01), showing the consistency of the ACE and BACE.

Table 6. Means of Variables and their Correlation Matrix for Third-year Group A

			Correlation		
	Mean	SD	EAT	ACE	BACE
EAT	8.106	1.656	-		
ACE	11.972	3.560	.273*	-	
BACE	9.917	2.250	.134	.515**	-

**p<.01, *p<.05, n=72.

Table 7. Means of Variables and their Correlation Matrix for Third-year Group B

			Correlation		
	Mean	SD	RST†	ACE	BACE
RST	2.500	.885	-		
ACE	12.583	3.599	.451*	-	
BACE	10.125	1.484	.282	.491*	-

*p<.05, n=24. †RST=ESL-RST

Table 8. Word-retaining Strategies in L-RST for First-year Group

	Elaborate			Non-elaborate		
	Imag.	SM	Trans.	Reh.	No	Total
Low	1	1	5	15	9	31
Medium	2	0	1	3	3	9
High	0	0	0	0	0	0
Total	3	1	6	18	12	40

n=40. Imag.=imaging, SM=sentence-making, Trans.=translation, Reh.=rehearsal, No=no-strategy.

Table 9. Word-retaining Strategies in J-RST for First-year Group

	Elaborate			Non-elaborate		
	Imag.	SM	Trans.	Reh.	No	Total
Low	0	0	0	12	13	25
Medium	4	4	0	3	3	14
High	0	0	0	1	0	1
Total	4	4	0	16	16	40

n=40. Imag.=imaging, SM=sentence-making, Trans.=translation, Reh.=rehearsal, No=no-strategy.

Table 10. Elaborate and Non-elaborate Strategies for Low and Higher Groups

		Elaborate	Non-elaborate	Total
L-RST	Low	7	24	31
	Higher	3	6	9
J-RST	Low	0	25	25
	Higher	8	7	15

n=40.

3.5. Word-retaining Strategies in L-RST and J-RST

Tables 8 and 9 show the numbers of word-retaining strategies that the first-year group used in the L-RST and J-RST. The students were divided into groups with low, medium and high working memory capacity (low, medium and high capacity groups) according to their reading spans below three, three and above three respectively (Daneman & Carpenter, 1980).

In both of the L-RST and J-RST, the students used more non-elaborate than elaborate strategies (L-RST: elaborate=10, non-elaborate=30; J-RST: elaborate=8, non-elaborate=32). Considering that non-elaborate and elaborate strategies are used in phonological and semantic processing of information respectively (Osaka & Nishizaki, 2000), the first-year students seem to have depended more on phonological than semantic processing in retaining words.

Next, since the numbers of high capacity students were null and one in the L-RST and J-RST respectively, we combined the medium and high capacity groups into higher capacity groups, and compared the distributions of elaborate and non-elaborate strategies between the low and higher capacity groups (Table 8).

In the L-RST, the strategy distributions looked rather similar between the two groups (Low: elaborate=7, non-elaborate=24; Higher: elaborate=3, non-elaborate=6), which was supported by the Fisher's test (df=1, χ^2=.430, ns). In the J-RST, on the other hand, the two groups were distinctive in their distributions of the strategies (Low: elaborate=0, non-elaborate=25; Higher: elaborate=8, non-elaborate=7). This was confirmed by the Fisher's test, showing a significant difference in the distributions between the low and higher capacity groups (df=1, χ^2=16.667, p<.01). The different distributions of the word-retaining strategies between the two RSTs may have been due to the students' automatic phonological coding in the J-RST where their mother tongue was used.

4. DISCUSSION

4.1. Research Question (1)

The first research question inquired into differences in the efficiencies of phonological coding and working memory capacities between the first- and third-year senior high school students. The results showed that: (a) there was no significant difference in the efficiencies of phonological coding as measured by the EAT between the first- and third-year students; and (b) the third-year students had significantly higher working memory capacities than the first-year students.

The result (a) was surprising in refuting our speculation that phonological coding of the third-year students would be more efficient than that of the first-year students. This result suggests that the third-year students did not improve their efficiencies of phonological coding during the first two years. Although the students might have highly developed their decoding skills before entering the senior high school, this possibility is refuted by the above research finding that the efficiency of phonological coding in terms of oral reading speed was improved by oral reading practice for senior high school students (Section 1).

The lack of teaching decoding skills including phonological coding may have been responsible for the result, which consequently may have led to the third-year students' underdeveloped reading comprehension skills. In this case, we should adopt the teaching of decoding skills such as oral reading practice, as recommended in L 1 reading pedagogy (Grabe & Stroller, 2002, Snow, et, al., 1998).

The result (b) seems to show that the third-year students did improve their working memory capacities during the first two years. This result complies with Siegel's (1994) finding that adolescents are still at developing stages of their working memory capacities. In this case, we can possibly help students to expand their working memory capacities by introducing cognitively demanding activities, such as oral reading practice, which are more likely to activate working memory to a higher level (Osaka, et al., 1999, Osaka, 2002), into reading and general English language pedagogy.

4.2. Research Question (2)

The second research question asked about the relationships of the efficiencies of phonological coding and working memory capacities with reading comprehension for the first- and third-year senior high school students. The results showed that: (a) in both the first- and third-year students there were significant correlations between the efficiencies of phonological coding and reading comprehension as measured respectively by the BACE (r=.655, p<.01) and by the ACE (r=.273, p<.05); and (b) in the first-year students there was no significant correlation between working memory capacities and reading comprehension, whereas in the third-year students there was a significant correlation between the two variables (r=.451, p<.05).

Although the result (a) was congruous with the result in the last section that the first- and third-year students had similar efficiencies of phonological coding, the two groups of students were distinctive in the reading comprehension variances that the efficiencies of phonological coding explained (first-year=42.9%, third-year=7.5%). Moreover, the third-year students had no significant correlation between the two variables when their reading comprehension was measured by the BACE.

Since phonological coding was the primary predictor of the reading comprehension variance for the first-year students, it seems to have made a far greater contribution to reading comprehension than syntactic parsing and other higher level processing. Probably, the first-year students were more dependent upon non-automatic phonological coding for lexical processing of information than the third-year students. They may also have possessed only unskilled strategies for higher level processing.

In contrast, the third-year students, having significantly better reading comprehension (Mann-Whitney U=516.500, $p<.01$) but about the same efficiencies of phonological coding, were supposedly more adept at syntactic parsing and other higher level processing than the first-year students. The third-year students may also have had information lexically accessed more directly than the first-year students, bypassing phonological coding, as are Japanese Kanji characters often processed (Rayner & Pollatsek, 1989).

The result (b) is in line with the above result that the third-year students had significantly higher working memory capacities than the first-year students (Section 4.1). However, working memory capacities and reading comprehension of the third-year students were not significantly correlated when their reading comprehension was measured by the less difficult assessment, BACE. Since the correlation for the third-year students was significant only when their reading comprehension measure was the more difficult ACE, it was confirmed that working memory was more likely to activate itself with a more cognitively loaded activity (Section 1).

On the other hand, the first-year students, using their working memory capacities mainly for lower level processing such as phonological coding, may not have had enough capacities left for other essential functions of working memory, i.e., syntactic parsing and other higher level processing such as comprehension.

4.3. Research Question (3)

The third research question explored whether the relationships of the efficiencies of phonological coding and working memory capacities with reading comprehension were reflected in the word-retaining strategies of the first-year students. The results concerning the use of word-retaining strategies were: (a) the students used more non-elaborate than elaborate strategies in both of the L-RST and J-RST; (b) the higher capacity students used significantly more elaborate strategies than the low capacity students in the J-RST; and (c) the higher and low capacity students similarly used more non-elaborate than elaborate strategies in the L-RST.

The result (a) shows that the first-year students depended more greatly on phonological processing than semantic processing in retaining words, complying with the significant correlation between the efficiency of phonological coding and reading comprehension. Thus, this is interpreted as reflecting the relationship between the two variables of the first-year students in their word-retaining strategies. This phenomenon may be taken for granted because both reading comprehension and the RSTs are cognitively demanding activities that require the processing and storing of information simultaneously.

In the result (b), since the students' phonological coding of Japanese words was automatic in the J-RST, barely half of the higher capacity students, with the elaborate strategies developed, seem to have had enough working memory capacities left for semantic processing of words simultaneously with reading the text aloud. The other higher capacity students, who used the non-elaborate strategies, may have been still at learning stages of elaborate strategies.

On the other hand, for the low capacity students, who used the non-elaborate strategies, their working memory capacities were not high enough to use any elaborate strategies despite the advantageous condition, i.e., automatic phonological coding of Japanese words, even if they might have developed elaborate strategies.

The result (c) can also be accounted for in terms of working memory capacity. Although the higher and low capacity students used three and seven elaborate strategies respectively, this may have been an artifact of our strategy categorization. If "translation" strategy, which is not in the J-RST, were taken out, the numbers of "imaging" and "sentence making" strategies would make equally two for the higher and low capacity students. Considering these four students possessed higher working memory capacities using the elaborate strategies in the J-RST, even higher capacity students in the J-RST seem to have had difficulty sparing their working memory capacities for higher level processing than phonological coding in the L-RST. This likelihood of using up working memory capacity for phonological coding in reading English may have been responsible for the moderate correlation between the J-RST and L-RST ($r=.465$, $p<.01$). It seems that the insignificant correlation between working memory capacity and reading comprehension of the first-year students was also reflected in their word-retaining strategies.

5. CONCLUSION

The present study investigated into the differences between first- and third-year senior high school students concerning: (a) the efficiencies of phonological coding and working memory capacities; and (b) the relationships of these two variables with reading comprehension. Also explored was whether the relationships were reflected in word-retaining strategies that the first-year students used in the RSTs for measuring working memory capacities.

Our main findings are: (a) the students may not improve the efficiencies of phonological coding during the first two years of senior high school, probably because of the lack of teaching decoding skills; (b) the students may improve their working memory capacities during the first two years as previous research shows; (c) in the first-year students, who are dependent more on phonological than semantic processing of information, there is a higher correlation between the efficiency of phonological coding and reading comprehension; (d) in the third-year students, who are more adept at higher level processing of information with higher working memory capacities, there is a correlation between working memory capacity and reading comprehension; and (e) most of the first-year students, reflecting the relationships of the two variables and reading comprehension, tend to use more non-elaborate than elaborate word-retaining strategies, due to their tendency of using up working memory capacities on phonological coding.

Implications for reading and general English language pedagogy are: (a) we should acknowledge the need to teach decoding skills including phonological coding for the improvement of reading comprehension; (b) we should acknowledge the relationship between working memory capacities and reading comprehension for older senior high school students with higher English proficiency; and (c) we should use such tasks and activities as oral reading that may help learners to improve the efficiencies of phonological coding and working memory capacities.

Limitations of this study include: (a) the use of familiar words in the EAT; (b) the first-year group had no high capacity students in both the L-RST and J-RST; (c) the correlation between the L-RST and J-RST was not high; and (d) only the word-retaining strategies of the first-year students were analyzed.

The use of unknown words in the EAT might have generated a significant difference in the mean efficiencies of phonological coding between the first- and third-year students. Weaknesses (b) and (c) cast doubt on the reliability of the RSTs. The analysis of the strategies of the third-year students with better reading comprehension might have revealed different distributions of the strategies.

Therefore, we should replicate this study with a better research design so that the findings will be confirmed. We should also explore tasks and activities such as oral reading practice in order to enhance the efficiencies of phonological coding and working memory capacities. Further, these tasks and activities including oral reading practice should be put to trial and their effectiveness should be examined in terms of the improvement of learners' reading and general English proficiency.

Notes

1. Capacity Constrained Comprehension (Just & Carpenter, 1992) asserts: (a) working memory deals with both the storage and processing of activated information simultaneously; (b) working memory is constrained in its processing resources; (c) the trading off between storage and processing occurs if the activated information exceeds the working memory capacity; and (d) individual differences in working memory capacity are reflected in their cognitive activities.
2. In Miyasako (2002, 2003), oral reading ability was analytically measured based on four criteria, i.e., pronunciation, intonation, pause-making and delivery.
3. In Miyasako (2002, 2003), English language ability is defined as language ability, which can be developed in the EFL instruction in Japan, to make a part of English proficiency with reading, grammar and vocabulary for its main components. On the other hand, English proficiency includes global English language performance as well as its competence (McNamara, 1996).
4. Association for English Language Proficiency Assessment (ELPA) generously gave us a permission to use the past versions of *Assessment of Communicative English* and *Basic Assessment of Communicative English* for this research.
5. Cronbach coefficient alphas of the ACE and BACE in Miyasako (2004) were .725 and .742 respectively ($p<.01$, $n=78$).
6. According to Daneman & Carpenter (1980), the RST measures one's working memory capacity used for processing and storing information simultaneously. In the test, one reads aloud three or five sets of 13- to 16-word sentences, and recalls the final word of each sentence at the end of each set. The number of sentences in each set increments from two to five or six as far as one can

recall the final words perfectly. One's reading span is represented as the maximum number of sentences whose final words she can recall perfectly in two out of three sets or three out of five sets.

7. The standard procedure of the RST (Daneman & Carpenter, 1980) is as follows: (a) the examiner shows one card with a sentence on it; (b) the examinee reads the sentence aloud at her pace; (c) the examiner shows the next card soon after the last sentence is read; (d) the examiner and examinee repeat these steps until no sentences of the set are left; and (e) the examinee recalls the final words of the sentences, given the examiner's signal. These steps continue until the examinee can no longer recall the final words perfectly.

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Appendix A. 40 Words in English Word Articulating Test

someone, difficult, yesterday, communicate, airplane, grandfather, beautiful, question, hometown, computer, welcome, language, Christmas, newspaper, Spanish, international, remember, elephant, baseball, yourself, usually, vegetable, Japanese, Southeast, hamburger, important, American, birthplace, difference, Indonesia, dictionary, mountain, Halloween, restaurant, however, tomorrow, interesting, overseas, understand, December.

Appendix B. L-RST (one set)

2 sentences. That hard fight was ten hours long. There was a piano contest for children. ***3 sentences.*** Yesterday I didn't understand the question. You can write on this little table. French teachers gave us some apple pies. ***4 sentences.*** We like traveling around the world. She learned about Canada in a lesson. Our friends visited an old art museum. Many people went to Paris last week. ***5 sentences.*** Please bring the tigers to our city. There are many differences between them. Her aunt and uncle are nice teachers. Many American children live in this area. She knows wine is made from grapes. ***6 sentences.*** Plastic is usually lighter than glass. In the US many people speak Spanish. The earth is larger than the moon. That was a surprise to her father. We can move our hands like this. Ken liked studying better than playing.