Relative Contribution of Working Memory Capacity to L2 Reading Comprehension

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The aim of the present study is to explore the relative contribution of working memory capacity to second language reading comprehension of Korean college students in comparison with L1 reading comprehension ability, L2 vocabulary knowledge, and L2 grammatical knowledge. Further, it attempts to examine whether the role played by working memory span differs depending on the proficiency levels of L2 learners. The study was conducted with 78 L2 learners of English who were classified into two different groups—a low-proficiency and a high-proficiency group—according to their English proficiency levels. The results of a step-wise multiple regression analysis revealed that working memory capacity made a significant contribution to L2 reading comprehension of advanced users of English above and beyond other variables; working memory capacity alone explained around 37.9% of the variance in L2 reading comprehension. However, for the low-proficiency group, vocabulary knowledge explained a larger variance in L2 reading comprehension. The findings from the study suggest that as L2 learners become more competent users of English, working memory span emerges as a more direct predictor of L2 reading comprehension.

Key words: working memory span, L2 reading comprehension, reading span task, L2 vocabulary knowledge, L2 grammatical knowledge

1. INTRODUCTION

Reading has been described as a complex and dynamic process in nature because it draws from a multitude of variables in which readers construct meaning from the text. According to Alderson (2000), different types of variables that might affect the reading process involve text variables (e.g., text structure, genre, text topic and length) and reader variables (e.g., background knowledge, motivation and memory constraints). Among the
numerous factors possibly coming into play, the role of working memory as one reader variable influencing the reading process has gained considerable interest from many researchers for several decades (e.g., Baddeley & Hitch, 1974; Daneman & Carpenter, 1980; Engle, Cantor, & Carullo, 1992; Friedman & Miyake, 2004; Just & Carpenter, 1992; Turner & Engle, 1989; Waters & Caplan, 1996). In broad terms, working memory is defined as “an integrated system for temporarily storing and manipulating information” (Baddeley, 2003, p. 837). That is, working memory commonly involves two main functions, with one being on-going processing and the other being the simultaneous storage of information; together they play an important role in complex cognitive activities, such as learning, reasoning and language comprehension (Baddeley, 1986; Just & Carpenter, 1992).

As for reading comprehension in particular, working memory has been conceived as one of the prevailing factors which may influence the comprehension processes (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985). For example, a reader needs to decode words and interpret the meaning from the context while remembering what has already been read from the text (Daneman & Carpenter, 1980; Kintsch & van Dijk, 1978). In this respect, working memory is relevant to reading because it is responsible for holding the information temporarily while processing the subsequent information at the same time (Lipka & Siegel, 2012; Osaka, Nishizaki, Komori, & Osaka, 2002). Thus, working memory has received increased attention from many researchers in the reading field.

The possible relationship between working memory span and reading comprehension has been investigated from various perspectives (e.g., Alptekin & Erçetin, 2009, 2010; Daneman & Carpenter, 1980; Engle et al., 1992; Friedman & Miyake, 2004; Linderholm & van den Broek, 2002; Turner & Engle, 1989; Walter, 2004; Waters & Caplan, 1996). In earlier studies, researchers developed different types of working memory span measures in an attempt to examine the potential links between working memory capacity and reading comprehension ability (e.g., Daneman & Carpenter, 1980; Cain & Oakhill, 2006; Turner & Engle, 1989; Waters & Caplan, 1996; Yuill, Oakhill, & Parkin, 1989). With the various kinds of working memory span measures, seminal studies have provided evidence supporting the argument that working memory capacity is statistically correlated with both L1 and L2 reading comprehension ability (e.g., Daneman & Carpenter, 1980; Friedman & Miyake, 2004; Harrington & Sawyer, 1992; Walter, 2004; Waters & Caplan, 1996).

Enlightening and informative studies to date have confirmed that working memory span can be viewed as one of the cognitive variables that help explain individual differences in reading comprehension. However, to date, only a scant amount of research has been done to explore the relative contribution of working memory span to L2 reading comprehension in relation to other critical factors known to affect L2 reading comprehension performance. Thus, the present study attempts to contribute to this line of research by examining the
nature of working memory, particularly focusing on the relative contribution of working memory capacity to L2 reading comprehension of Korean college students in comparison with three other important factors: L1 reading comprehension ability, L2 vocabulary knowledge, and L2 grammatical knowledge. L1 reading ability has been found to be a specific attribute of L2 readers which may influence L2 reading performance (Grabe, 2009). Additionally, L2 vocabulary knowledge and L2 grammatical knowledge have been recognized as important factors in determining L2 reading ability (Grabe, 2009; Koda, 2005; Urquhart & Weir, 1998).

2. LITERATURE REVIEW

2.1. Working Memory Capacity

Working memory has been conceptualized as a limited-capacity storage and information manipulating system—usually auditory, visual, or spatial—that is necessary for carrying out a wide range of tasks (Baddeley, 1986, 2003). Baddeley (1986) proposed a model of working memory which has been one of the most widely referred to models consisting of three components: a central executive, a phonological loop and a visuo-spatial sketchpad. The central executive is the task control center which is responsible for directing attentional processes and allocating cognitive resources. The phonological loop stores and rehearse auditory information temporarily, while the visuo-spatial sketchpad processes and stores visual images and spatial relations. More recently, a new sub-component, the episodic buffer, has been added to the model (Baddeley, 2003). It is responsible not only for combining the auditory and the visual codes but also for integrating information from a variety of systems including long-term memory.

In an attempt to assess the working memory capacity of students, different types of working memory span measures have been developed (Daneman & Carpenter, 1980; Gathercole & Baddeley, 1993; Turner & Engle, 1989; Yuill et al., 1989). The measures can be classified into two broad categories, the simple span task and the complex span task (Schüler, Scheiter, & van Genuchten, 2011). Simple span tasks, such as the digit span (Yuill et al., 1989) and non-word repetition test (Gathercole & Baddeley, 1993), are likely to tap into simple storage functions. In the digit span, the participants are presented with groups of digits to read aloud and recall the final digit of each group. The non-word repetition test includes a list of nonsense words to be recalled (Baddeley, Gathercole, & Papagno, 1998). Complex span tasks, on the other hand, are designed to measure central executive capacity. In these tasks, participants are required to store information while performing some type of cognitive activity. The operation span task (Turner & Engle,
1989) and the reading span task (Daneman & Carpenter, 1980) are the most commonly used complex span tasks to measure the capacity of the central executive. The operation span task requires the participants to solve simple arithmetic operations and to remember a word or letter that appears followed by each equation (Conway et al., 2005); on the other hand, the reading span task generally consists of unrelated simple sentences, with each sentence ending with a different word. As participants view the sentences, they are asked to read aloud the sentence presented and to recall the final word of each sentence (Daneman & Carpenter, 1980).

2.2. Working Memory Capacity and L1 Reading Comprehension

In recognizing the possible role played by working memory capacity in performing cognitive tasks, researchers have attempted to investigate how individual differences in working memory capacity can be considered as a variable in L1 reading abilities (e.g., Daneman & Carpenter, 1980; Friedman & Miyake, 2004; Just & Carpenter, 1992; Waters & Caplan, 1996). One of the most seminal studies was conducted by Daneman and Carpenter (1980), who first developed the reading span task (RST) to measure working memory capacity through reading sentences and recalling the final words. The result of the study conducted on college students by Daneman and Carpenter (1980) revealed that students' performance on the reading span task correlated with three reading comprehension measures, which included the verbal section of the SAT, the fact retrieval test and the pronominal reference test.

Friedman and Miyake (2004) also investigated how working memory span correlated with reading comprehension using the RST as a measure of working memory span. In this study, the participants were divided into either an experimenter-administered group or a participant-administered group, based on how the test was administered. The result of the study indicated a moderate correlation between the reading span task and reading comprehension test for both groups. Linderholm and van den Broek (2002) compared the performance in reading comprehension of two distinct groups: adult readers with a higher working memory span and adult readers with a lower working memory span. In their study, the RST was used to measure working memory capacity and the free recall task was employed to assess reading comprehension. They showed that readers with low working memory capacity tended to recall less data than participants with high working memory capacity when they read for study purposes.

Yuill et al. (1989) also investigated the correlation between working memory capacity and reading comprehension ability of 7- and 8-year-olds using a digit span task which incorporated a series of digits in the task instead of a series of sentences. The results of this study supported the hypothesis that working memory capacity had a correlation with the
reading comprehension levels of children. Turner and Engle (1989) used the operation span task and reported a relationship between performance on the operation span task and reading comprehension ability. In addition, an alternative version of the RST was developed by Waters and Caplan (1996). They adopted a different scoring system from that of Daneman and Carpenter’s RST (1980) in a way that it included (a) the number of final words recalled, (b) the number of sentences correctly judged and (c) the mean reaction time of the sentences correctly judged. From the study, the predictive role of working memory span in reading comprehension was discovered; a moderate correlation between performance on the working memory span measure and reading comprehension test scores was reported.

Comparable studies have also been conducted on Korean students. Lee and Kim (2003) examined the relationship between performance on the working memory span measure and reading comprehension ability of sixth grade elementary students in Korea. These students were required to perform working memory span tests which consisted of a star counting task, a spatial integration task and the RST. The students’ L1 reading ability was assessed with a task called “error detection.” It was found that students with high working memory capacity performed significantly better than students with low working memory capacity. Lee (2011) speculated whether working memory capacity predicted the reading comprehension processes, including word comprehension, sentence comprehension and text comprehension with college students. In the study, working memory capacity was found to correlate significantly only with sentence comprehension ability.

However, not all studies have discovered a meaningful connection between working memory span and reading comprehension. For instance, Cain and Oakhill (2006) reported findings which were somewhat different from the aforementioned studies. In their study, two groups of participants were classified as either good or poor comprehenders according to the results of the Neale analysis of reading ability (revised British edition). These two groups completed two assessments of working memory: (a) a listening task in which participants were required to provide a single word completion for a sentence spoken by the experimenter and to remember that same word for later recall; (b) the digit span. The results indicated that the two groups – good comprehenders and poor comprehenders – did not differ in their performance on the digit span task.

2.3. Working Memory Capacity and L2 Reading Comprehension

The results of the studies which suggested potential links between working memory span and L1 reading comprehension have motivated L2 researchers to examine how differences in L2 reading abilities can be attributed to differences in working memory capacity (e.g., Alptekin & Erçetin, 2009, 2010; Harrington, 1992; Harrington & Sawyer,
1992; Leeser, 2007; Osaka & Osaka, 1992; Osaka, Osaka, & Groner, 1993). Harrington and Sawyer (1992) examined the possible role played by working memory capacity in L2 reading comprehension with Japanese college students who were advanced learners of English. The digit span, the word span and the reading span task were used to measure the participants’ working memory span. The grammar and reading sections of the TOFEL were used to assess the participants’ L2 reading comprehension ability. It was discovered that learners with higher scores on the reading span task performed better on the L2 reading comprehension test. Service, Simola, Metsaenheimo, and Maury (2002) also used the RST to measure working memory capacity of Finnish university students learning English as a second language; a significant correlation was reported between performance on the RST and scores from the reading section of the Cambridge Certificate of Proficiency.

Walter (2004) used Waters and Caplan’s (1996) version of the reading span task, which included composite scores of the number of final words recalled, the number of correctly judged sentences, and the mean reaction time for correctly judged sentences. From the study, it was found that verbal working memory span correlated significantly with reading comprehension ability, which was measured by the summary completion task. Furthermore, a computerized version of Waters and Caplan’s (1996) RST was used in Leeser’s study (2007) to investigate the role played by working memory capacity in L2 reading comprehension. Leeser’s study (2007) was conducted on 94 adult learners of Spanish to examine the effects of topic familiarity and working memory capacity on L2 reading comprehension as well as on the processing of future tense morphology. The findings from the study suggested that participants with higher working memory capacities generally performed better in comprehending the text; however, the result was only applicable when participants were familiar with the passage topic.

More recently, Alptekin and Ergçetin (2009) modified the original version of the RST by adopting a procedure proposed by Waters and Caplan (1996). In the RST, participants were asked to read aloud sentences and make grammaticality judgments as processing tasks. In addition, in order to measure storage capacity, two different tasks were employed, namely, the recall task and the recognition task. The purpose of the study was to examine the role of working memory span in L2 reading comprehension, specifically, literal and inferential comprehension. The results revealed a significant role played by working memory in inferential comprehension, one condition being that storage was measured through a recall-based procedure. Although a significant role of working memory capacity in L2 reading has been observed in a majority of previous studies, contradictory findings have also been reported. For instance, Chun and Payne (2004) investigated the relationship between individual differences in working memory span and L2 reading comprehension ability with 13 students in a second-year German language course. They used the non-word repetition and a version of Daneman and Carpenter’s (1980) RST to measure working
memory capacity. In this study, the results yielded no significant correlation between working memory span and L2 reading comprehension ability.

The predictive role of working memory capacity in L2 reading comprehension has begun to gain attention from several researchers in Korea as well. For instance, Sok (2005) examined the relationship between working memory and difficulties in second language reading (English) with middle school students in Korea. The results showed that students with higher working memory capacity attained higher scores on the L2 reading tests than students with lower working memory capacity. Sok (2005) concluded that working memory capacity had significant effects on L2 reading comprehension. In the Korean context, several studies have explored the nature of working memory capacity in relation to diverse aspects of second language learning, such as vocabulary acquisition (Bae, 2012; Jung & Choi, 2012; Kim, 2011), grammatical judgment ability (Baik, Lee, & Kim, 2013; Baik, Lee, Kim, & Lee, 2012) and sentence processing (Choe, 2011). However, there is a paucity of research which directly focuses on the relationship between working memory capacity and L2 reading comprehension of Korean students learning English as a foreign language. It is evident that further in-depth research with appropriate working memory span measures, diverse L2 reading comprehension tests, and students at various proficiency levels would provide a better understanding of how working memory capacity relates to L2 reading comprehension of Korean students.

2.4. Contribution of Working Memory Capacity to Reading Comprehension

The role played by working memory in reading comprehension has been extensively studied; nevertheless, in the majority of previous studies investigating the role of working memory capacity in reading comprehension, working memory capacity has been treated as an overriding variable that might account for variance of reading comprehension. It has been also recognized that working memory capacity should be analyzed in comparison with other well-established predictors of comprehension, such as decoding, word recognition skill and vocabulary knowledge to explain individual differences in reading comprehension (Swanson & Berninger, 1995; Yuill et al., 1989). Following this line of thought, Cain, Oakhill, and Bryant (2004) examined the relative predictive power of working memory span along with vocabulary knowledge and verbal ability in order to determine their relationship to reading comprehension of 102 children who were seven and eight years old. In the study, two different working memory measures, the sentence span task (central executive) and the digit span task (phonological loop), were utilized. From a statistical analysis using hierarchical multiple regression, the results showed that the combined working memory span explained significant variance in reading comprehension above and beyond the contribution made by other variables. They concluded that working
memory was one of the most prevalent factors that could explain individual differences in comprehension ability and comprehension development.

Seigneuric, Ehrlich, Oakhill, and Yuill (2000) also investigated the relative contribution of working memory capacity to reading comprehension in comparison with vocabulary and decoding skills. The study was conducted on 48 fourth grade children and revealed that working memory capacity was a direct predictor of reading comprehension when compared with vocabulary and decoding skills. Seigneuric and Ehrlich (2005) further investigated whether the relative contribution of working memory capacity to reading comprehension would change depending on the participants’ development through a longitudinal study; they examined the developmental change of the contribution made by working memory capacity along with vocabulary and decoding skills to reading comprehension of elementary school students. Multiple regression analyses were performed at three different points: when the children were 7, 8, and 9 years old. It was found that decoding skills and vocabulary knowledge accounted for more variance of reading comprehension in the earlier years; however, working memory capacity eventually became a direct predictor of reading comprehension once the children reached 9 years old.

In fact, one recent study was done on the issue of the relative predictive power of working memory span with Korean college students (Choi, 2013). In the study, the predictive power of working memory in L2 reading comprehension, encompassing both literal and inferential comprehension, was examined in comparison with vocabulary knowledge. Choi (2013) reported that when working memory capacity and vocabulary knowledge were combined together, they accounted for 21.7% of variance in L2 literal reading comprehension. However, when it came to inferential comprehension, vocabulary knowledge was the single predictor and accounted for 36.3% of the variance. Thus, he concluded that vocabulary knowledge was a stronger predictor of reading comprehension at both levels—literal and inferential comprehension—than working memory capacity. The finding from Choi’s study (2013) was enlightening, in that it yielded different results than the studies conducted in the L1 reading field. However, in his study, only advanced EFL learners were included; hence, it seems more interesting to examine whether the significance of each variable may differ depending on the participants’ proficiency levels.

Previous seminal studies have confirmed that working memory span can be counted as one of the variables in explaining individual differences of reading comprehension. However, in a majority of the studies, working memory capacity has been treated as a sole predictor of either L1 or L2 reading comprehension (e.g., Daneman & Carpenter, 1980; Harrington & Sawyer, 1992; Waters & Caplan, 1996). However, for L2 reading comprehension in particular, other variables such as background knowledge, learners’ L1 reading ability, L2 vocabulary knowledge, and decoding skills are known to play critical roles as well (Alderson, 2000). Apparently, there has not been a study which explores the
relative predictive power of working memory capacity in L2 reading comprehension in
comparison with L1 reading ability, L2 vocabulary knowledge and L2 grammatical
knowledge. Therefore, the present study attempts to contribute to the line of research by
examining the relative contribution of working memory capacity to L2 reading
comprehension with college students who learn English as a foreign language.

1. Does working memory capacity make the most significant contribution to L2
   reading comprehension of less proficient learners of English in comparison with
   L1 reading ability, L2 vocabulary knowledge, and L2 grammatical knowledge?
2. Does working memory capacity make the most significant contribution to L2
   reading comprehension of more proficient learners of English in comparison with
   L1 reading ability, L2 vocabulary knowledge, and L2 grammatical knowledge?

3. METHOD

3.1. Participants

A total of 78 college students participated in the study. The participants’ English
proficiency levels were initially screened with their TOEIC scores, varying from 500 to
900. The participants were classified into two groups, either a high-proficiency ($n = 40$) or
a low-proficiency group ($n = 38$), based on the mean score of a reading comprehension test
in the L2 ($M = 12.0$). They were divided into two groups (i.e., high- and low-proficiency
group) rather than into three groups (i.e., high-, intermediate-, and low-proficiency group)
in consideration of the sample size needed for statistical analysis (e.g., multiple regression
analysis). Their TOEIC scores were used to validate candidate legitimacy.

3.2. Materials

3.2.1. Reading span task in L2 (English)

The participants’ working memory capacity was measured with the reading span task in
English (L2), as it was found that a more direct relationship exists between L2 working
memory span and L2 reading comprehension; in fact, it has been suggested that the
working memory span task in the L2 should be used if the purpose of a study is to
investigate the potential role of working memory span in L2 reading comprehension
(Alptekin & Erçetin, 2010). In the present study, the reading span task (RST) in L2
(English) was developed based on the procedure proposed in the Harrington and Sawyer’s
(1992) study. They simplified the original version of the RST developed by Daneman and Carpenter (1980) for the participants who were learners of English. The RST in the current study consisted of 42 unrelated simple sentences, each sentence being 11 to 13 words in length. The sentences were carefully constructed by ensuring that all of the sentences were declarative and affirmative statements. They were also active voice sentences ending with different one-syllable nouns. The test included 4 different sets, numbered from set 2 to set 5; set 2 consisted of 2 sentences and its sentence count incrementally increased and matched the level number up to set 5, which was composed of 5 sentences. In each set, there were three different trials. Among the 42 sentences, half of them were plausible in terms of grammaticality and meaning; the other half of them were implausible sentences. The implausible sentences were formulated based on the procedure suggested by Harrington and Sawyer (1992), whereby the orders of four to six words which came in front of the final word were unscrambled. In the present study, a computerized version of the RST was developed using E-prime 2.0 Professional (Appendix A).

3.2.2. Test for depth knowledge of L2 (English) vocabulary

The test for depth knowledge of vocabulary developed by Qian and Schedl (2004) was used in the present study. In the original version, there were 40 questions. However, 4 questions were omitted after reflecting on the advice of native speakers of English who explained that the choices given for these questions could be debatable. Therefore, the total number of questions was 36 in the current study. In each question, the participants were given an adjective as a stimulus word and were asked to choose the correct answers from 8 choices. The purpose of the test was to assess two aspects of vocabulary knowledge, which were word meaning and word collocation; hence, the choices were divided into two different columns, each column having a set of 4 choices, with one set being choices for synonyms and the other being choices for words that could be used together. There were three different options in choosing the correct answers: (a) 2 correct answers from a set of synonyms and 2 correct answers from a set of the words that could be used together; (b) 1 correct answer from a set of synonyms and 3 correct answers from a set of the words that could be used together; and (c) 3 correct answers from a set of synonyms and 1 correct answer from a set of the words that could be used together (Appendix B).

3.2.3. Test for breadth knowledge of L2 (English) vocabulary

To assess breadth knowledge of vocabulary, the test used in the study of Schmitt, Schmitt, and Calpham (2001) was adopted. There were 5 different levels, from 2000 word—family level, 3000 word—family level, 4000 word—family level, academic level,
to 5000 word—family level. At each level, there were 10 questions with each question composed of six words and three matching definitions (Appendix B).

3.2.4. Test for L2 (English) grammatical knowledge

The participants’ grammatical knowledge was determined using 40 sentences, half of which were grammatically correct with the other half being grammatically incorrect. The participants were asked to make a judgment as they read the sentence (Appendix B).

3.2.5. L2 (English) reading comprehension test

The reading comprehension test in L2 (English) was similar to a practice test used to prepare for the reading section of TOEFL PBT. In the test, there were 4 reading passages, with each one consisting of four multiple-choice questions. The length of each reading passage was held constant between 280 and 345 words. The questions for each passage varied, being either literal or inferential questions (Appendix C).

3.2.6. L1 (Korean) reading comprehension test

The reading comprehension test in L1 (Korean) was adopted from the Korean CSAT (College Scholastic Aptitude Test). Similar to the reading comprehension test in the L2, 4 different passages on various topics were included in the L1 reading comprehension test. Each passage was paired with 4 multiple-choice questions, which were either literal or inferential questions. The length of each passage was held constant between 298 and 341 words (Appendix C).

3.3. Data Collection Procedures

The tests were administered on two separate days. There was a one-week gap between the times when the reading comprehension tests in the L1 and L2, and the two vocabulary tests were administered. In the first session, the tests were provided in the following order: the L2 (English) reading comprehension test, the grammatical knowledge test and the test for depth knowledge of vocabulary. On the second session, the tests were presented in a new order: the L2 (English) reading span task, the L1 (Korean) reading comprehension test, and the test for breadth knowledge of vocabulary. The reading span task was delivered on a computer and the others were presented as paper-pencil tests. The participants were able to arrange their own schedule for the two separate days, with an interval of one week.
3.3.1. L2 (English) reading span task

The participants were tested individually with the assistance of an instructor. Prior to the test, general instructions on the RST were provided in the participants’ L1 (Korean). The L2 reading span task was programmed in E-prime 2.0 Professional; accordingly, a series of sentences was presented on a computer screen. In addition, two buttons on the keyboard were marked with blue and red: (a) if the sentence was plausible, the participant pressed the blue button, and (b) if the sentence was implausible, the participant pressed the red button. As the participants began the test, they were informed of three important features that they needed to consider while performing the task: (1) making a correct judgment of the sentence; (2) remembering the final word for later recall; and (3) reading speed. A practice set was offered to help the participants to acclimate themselves to the procedure of the computerized RST. At the end of each trial in a particular set, they were asked to write down the final words on the paper in sequential order as they read the sentences on the screen. A blank screen with an asterisk was displayed while the participants wrote down the answers. Once the participants finished writing down the words and were ready to continue, the instructor pressed the button to begin the next trial or set. At the beginning of each set (from set 2 to 5), the instructor informed the participants of the number of sentences to be expected.

3.3.2. Tests for L2 (English) vocabulary and grammatical knowledge

For the vocabulary and grammatical knowledge tests, 20 minutes were allocated, respectively. Prior to the tests, the instructor provided detailed explanations. Supplementary materials such as dictionaries were not allowed to be used during the test.

3.3.3. L2 (English) and L1 (Korean) reading comprehension

The participants were asked to complete reading comprehension tests in both the L2 and L1, with each one being a maximum of 20 minutes in duration. Supplementary materials such as dictionaries were not allowed to be used during the test.
## TABLE 1

Data Collection Procedure

<table>
<thead>
<tr>
<th>Materials</th>
<th>Duration</th>
</tr>
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<tbody>
<tr>
<td>General Instruction</td>
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<tr>
<td>L2 Reading Comprehension Test</td>
<td>20 minutes</td>
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<tr>
<td>L2 Grammatical Knowledge Test</td>
<td>20 minutes</td>
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<td>L2 Depth Knowledge of Vocabulary Test</td>
<td>20 minutes</td>
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<tr>
<td><strong>Interval of 1 week</strong></td>
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<td><strong>Session 2</strong></td>
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<tr>
<td>L2 Reading Span Task</td>
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<tr>
<td>L1 Reading Comprehension Test</td>
<td>20 minutes</td>
</tr>
<tr>
<td>L2 Breadth Knowledge of Vocabulary Test</td>
<td>20 minutes</td>
</tr>
</tbody>
</table>

### 3.4. Data Analysis

#### 3.4.1. L2 (English) reading span task

The current study adopted the scoring system proposed by Waters and Caplan (1996). Within this scoring system, the score of the reading span task included three different components: (a) the number of final words correctly recalled; (b) the number of sentences correctly judged; and (c) mean reaction time for the sentences correctly judged. The scoring system suggested by Waters and Caplan (1996) was more likely to reflect the performance on measures of both processing and storage. The total number of final words correctly recalled represents the score of storage performance, whereas the other two—the number of sentences correctly judged and mean reaction time—were counted as an index of processing performance. Thus, one credit was given for each final word correctly recalled. As for measures of processing, the number of sentences that were correctly judged was counted and one credit was given for each correct answer. Additionally, in E-prime, the reaction time for participants reading a sentence and making a judgment was measured in milliseconds. The mean reaction time for correctly judged sentences was included in the data.

In addition, z-scores of the following three components were calculated: (a) the number of final words correctly recalled; (b) the number of sentences correctly judged; and (c) mean reaction time of sentences correctly judged. Furthermore, the z-scores of mean reaction time were multiplied by (-1) as a longer reaction time represented slower responses (Leeser, 2007; Walter, 2004). A composite score was calculated by averaging out the z-scores of the three components, which represented the total score of the reading span task for further analysis.
3.4.2. Test for depth knowledge of L2 (English) vocabulary

With a total number of 36 questions, the participants were asked to choose 4 correct answers for each question. Thus, each question had a maximum score of 4, which tallied up to a total possible score of 144.

3.4.3. Test for breadth knowledge of L2 (English) vocabulary

The test for breadth knowledge of vocabulary consisted of 5 different levels. In each level, there were 10 questions, and the participants were asked to choose three correct answers out of six choices for the definitions given. As each question had 3 correct answers, the maximum score for each level was 30 points. The total score for the test was 150.

3.4.4. Test for L2 (English) grammatical knowledge

The test for grammatical knowledge included 40 different sentences. One point was given for each correct answer, which tallied up to a maximum of 40 points.

3.4.5. L2 (English) and L1 (Korean) reading comprehension tests

Both reading comprehension tests in the L2 (English) and L1 (Korean) consisted of 4 passages, respectively. Each passage was accompanied by 4 questions, the maximum score for each passage being 4 points. The total score for each test was 16 points.

3.4.6. Statistical analysis

The two main statistical analyses that were employed in the study were a correlation analysis (Pearson product-moment correlation coefficients) and a stepwise multiple regression analysis. In addition, an independent t-test was administered to identify the significant differences between the two groups, the low- and the high-proficiency groups. The internal consistency of the working memory span measure was examined through Cronbach’s alpha. The internal consistence reliability coefficients for the number of final words recalled and the number of sentences correctly judged on the reading span task were found to be .822 and .768, respectively.
4. RESULTS

The descriptive statistics for all the measures, including the reading comprehension tests, the vocabulary knowledge tests, the grammatical knowledge test and the reading span task are presented in Table 2. The L2 reading comprehension test scores differed significantly between the low-proficiency group ($M = 10.05$) and the high-proficiency group ($M = 14.08$), and the independent $t$-test confirmed that this difference was significant between the two groups ($p < .01$).

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Descriptive Statistics for Measures</th>
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<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>$M$</td>
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<tr>
<td>L2 RC</td>
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<td>L1 RC</td>
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<td>L2 BVK</td>
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<td>L2 DVK</td>
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<td>L2 RST – No. words recalled</td>
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<tr>
<td>L2 RST – No. sentences judged</td>
<td>34.58</td>
</tr>
<tr>
<td>L2 RST - Mean reaction time</td>
<td>9101.27</td>
</tr>
</tbody>
</table>

Note. L2 RC: L2 (English) reading comprehension test, L1 RC: L1 (Korean) reading comprehension test, L2 BVK: Breadth knowledge of L2 vocabulary test, L2 DVK: Depth knowledge of L2 vocabulary test, L2 GK: L2 grammatical knowledge test, RST: L2 reading span task.

A correlational analysis was performed for all participants (Table 3). It was found that breadth vocabulary knowledge ($r = .872$, $p < .01$), depth vocabulary knowledge ($r = .842$, $p < .01$) and grammatical knowledge ($r = .843$, $p < .01$) show a strong correlation with L2 reading comprehension ability. However, both L1 reading comprehension ability ($r = .277$, $p < .05$) and working memory capacity ($r = .263$, $p < .05$) had a weak relationship with L2 reading comprehension ability.

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>Correlations among Measures for All Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L2 RC</td>
</tr>
<tr>
<td>1. L2 RC</td>
<td></td>
</tr>
<tr>
<td>2. L1 RC</td>
<td>.277*</td>
</tr>
<tr>
<td>3. L2 BVK</td>
<td>.872**</td>
</tr>
<tr>
<td>4. L2 DVK</td>
<td>.842**</td>
</tr>
<tr>
<td>5. L2 GK</td>
<td>.843**</td>
</tr>
<tr>
<td>6. L2 RST-Composite score</td>
<td>.263*</td>
</tr>
</tbody>
</table>

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

Note. L2 RC: L2 (English) reading comprehension test, L1 RC: L1 (Korean) reading comprehension test, L2 BVK: Breadth knowledge of L2 vocabulary test, L2 DVK: Depth knowledge of L2 vocabulary test, L2 GK: L2 grammatical knowledge test, RST: L2 reading span task.
test, L2 BVK: Breadth knowledge of L2 vocabulary test, L2 DVK: Depth knowledge of L2 vocabulary test, L2 GK: L2 grammatical knowledge test, RST-Composite Score: average z-scores of reading span task

However, the results differed between the two groups when the correlation was examined separately. For the low-proficiency group, compared to the reading span task scores \( r = .430, p < .01 \), the test score for breadth knowledge of vocabulary \( r = .635, p < .01 \), for depth knowledge of vocabulary \( r = .573, p < .01 \) and for L2 grammatical knowledge \( r = .443, p < .01 \) had a stronger correlation with the L2 reading comprehension test scores (Table 4). Referring to Table 5, for advanced learners of English, breadth knowledge of vocabulary test scores \( r = .520, p < .01 \), along with the test scores for depth knowledge of vocabulary \( r = .491, p < .01 \) and L2 grammatical knowledge \( r = .566, p < .01 \) were also found to have statistically significant correlation with the L2 reading comprehension test scores. However, it was found that the reading span task scores were more strongly correlated with the L2 reading comprehension test scores for this group above other variables \( r = .616, p < .01 \). In addition, a non-significant correlation between L1 reading comprehension ability and L2 reading comprehension ability was reported for both groups.

### TABLE 4

<table>
<thead>
<tr>
<th></th>
<th>L2 RC</th>
<th>L1 RC</th>
<th>L2 BVK</th>
<th>L2 DVK</th>
<th>L2 GK</th>
<th>L2 RST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. L2 RC</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. L1 RC</td>
<td>.168</td>
<td>--</td>
<td>.024</td>
<td></td>
<td>.073</td>
<td></td>
</tr>
<tr>
<td>3. L2 BVK</td>
<td>.635*</td>
<td>.130</td>
<td>.356*</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. L2 DVK</td>
<td>.573**</td>
<td>.188</td>
<td>.347*</td>
<td>.130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. L2 GK</td>
<td>.443**</td>
<td>.368*</td>
<td>.183</td>
<td>.347*</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>6. L2 RST-Composite score</td>
<td>.430**</td>
<td>.368*</td>
<td>.183</td>
<td>.347*</td>
<td>.103</td>
<td>--</td>
</tr>
</tbody>
</table>

** \( p < .01 \), * \( p < .05 \)

**Note.** L2 RC: L2 (English) reading comprehension test, L1 RC: L1 (Korean) reading comprehension test, L2 BVK: Breadth knowledge of L2 vocabulary tes, L2 DVK: Depth knowledge of L2 vocabulary test, L2 GK: L2 grammatical knowledge test, RST-Composite Score: average z-scores of reading span task
TABLE 5

Correlations among Measures for High-Proficiency Group

<table>
<thead>
<tr>
<th></th>
<th>L2 RC</th>
<th>L1 RC</th>
<th>L2 BVK</th>
<th>L2 DVK</th>
<th>L2 GK</th>
<th>L2 RST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. L2 RC</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. L1 RC</td>
<td>.040</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. L2 BVK</td>
<td>.520**</td>
<td>-.046</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. L2 DVK</td>
<td>.491**</td>
<td>-.025</td>
<td>.390*</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. L2 GK</td>
<td>.566**</td>
<td>-.066</td>
<td>.563**</td>
<td>.441**</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>6. L2 RST-Composite score</td>
<td>.616**</td>
<td>-.069</td>
<td>.445**</td>
<td>.395*</td>
<td>.553**</td>
<td>--</td>
</tr>
</tbody>
</table>

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

Note. L2 RC: L2 (English) reading comprehension test, L1 RC: L1 (Korean) reading comprehension test, L2 BVK: Breadth knowledge of L2 vocabulary test, L2 DVK: Depth knowledge of L2 vocabulary test, L2 GK: L2 grammatical knowledge test, RST-Composite Score: average z-scores of reading span task.

Further, a step-wise multiple regression analysis was conducted with the L2 reading comprehension scores as a dependent variable in order to examine the relative contribution of each variable to L2 reading comprehension ability. For all participants, it was found that vocabulary knowledge was the strongest predictor of L2 reading comprehension (Table 6). L2 breadth knowledge of vocabulary combined with L2 depth knowledge of vocabulary accounted for 81.7% of L2 reading comprehension ability ($R^2 = .817$). Grammatical knowledge was another direct predictor of L2 reading comprehension, with an additional variance of 2.5%.

TABLE 6

Results of Step-wise Multiple Regression Analysis for All Participants

<table>
<thead>
<tr>
<th>Steps</th>
<th>Variables</th>
<th>$R$</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$\Delta F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Breadth knowledge of vocabulary</td>
<td>.872</td>
<td>.760</td>
<td>.760</td>
<td>240.625</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>Depth knowledge of vocabulary</td>
<td>.904</td>
<td>.817</td>
<td>.057</td>
<td>23.347</td>
<td>.001</td>
</tr>
<tr>
<td>3</td>
<td>Grammatical knowledge</td>
<td>.917</td>
<td>.842</td>
<td>.025</td>
<td>11.574</td>
<td>.001</td>
</tr>
</tbody>
</table>

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

Note. $R$: the values of the multiple correlation coefficient between the predictors and the outcome, $R^2$: a measure of how much of the variability in the outcome is accounted for by the predictor, $\Delta R^2$: change in $R^2$

For the low-proficiency group, Table 7 shows that L2 breadth knowledge of vocabulary combined with L2 depth knowledge of vocabulary accounted for 50.5% of variance in L2 reading comprehension ability ($R^2 = .505$). Unlike the low-proficiency group, the L2 working memory capacity alone accounted for 37.9% of L2 reading comprehension ability ($R^2 = .379$), followed by L2 breadth knowledge of vocabulary for the high-proficiency group in Table 8. That is to say, L2 working memory capacity was found to be the
The strongest predictor of L2 reading comprehension for advanced learners of English is breadth knowledge of vocabulary.

### TABLE 7

<table>
<thead>
<tr>
<th>Steps</th>
<th>Variables</th>
<th>R</th>
<th>R²</th>
<th>ΔR²</th>
<th>ΔR²</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Breadth knowledge of vocabulary</td>
<td>.635</td>
<td>.403</td>
<td>.403</td>
<td>24.350**</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Depth knowledge of vocabulary</td>
<td>.711</td>
<td>.505</td>
<td>.102</td>
<td>7.215*</td>
<td>.011</td>
<td></td>
</tr>
</tbody>
</table>

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

Note. R: the values of the multiple correlation coefficient between the predictors and the outcome, R²: a measure of how much of the variability in the outcome is accounted for by the predictor, ΔR²: change in R²

### TABLE 8

<table>
<thead>
<tr>
<th>Steps</th>
<th>Variables</th>
<th>R</th>
<th>R²</th>
<th>ΔR²</th>
<th>ΔR²</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Working memory capacity</td>
<td>.616</td>
<td>.379</td>
<td>.379</td>
<td>23.185**</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Breadth knowledge of vocabulary</td>
<td>.674</td>
<td>.455</td>
<td>.076</td>
<td>5.131*</td>
<td>.029</td>
<td></td>
</tr>
</tbody>
</table>

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

Note. R: the values of the multiple correlation coefficient between the predictors and the outcome, R²: a measure of how much of the variability in the outcome is accounted for by the predictor, ΔR²: change in R²

From the results, it can be suggested that role played by working memory span differs depending on the proficiency level of L2 learners; it seems to become a stronger predictor as L2 learners become more competent users of English.

## 5. DISCUSSION

In the present study, the construct of working memory capacity, which has been conceived as one of the important cognitive resources in explaining individual differences in L2 reading comprehension, was explored. The relative contribution of working memory capacity to L2 reading comprehension ability was investigated in relation to L1 reading ability, L2 vocabulary knowledge and L2 grammatical knowledge, which are also known to be critical factors in understanding L2 reading performance. Particularly, the issue that has not been dealt with in the previous studies—whether the effects of working memory capacity may vary according to the proficiency level of L2 learners—was addressed in the current study.

From the results of a step-wise multiple regression analysis, it was found that the
Relative Contribution of Working Memory Capacity to L2 Reading Comprehension

contribution made by working memory capacity was different for each group. For the
low-proficiency group, vocabulary knowledge accounted for a larger variance than
working memory capacity in L2 reading comprehension; L2 breadth knowledge of
vocabulary combined with L2 depth knowledge of vocabulary explained around 50.5% of
the variance \( (R^2 = .505) \) in L2 reading comprehension (Table 7). That is, vocabulary
knowledge was the strongest predictor of L2 reading comprehension ability for less
proficient learners of English.

However, for the high-proficiency group, working memory span explained
approximately 37.9% of the variance \( (R^2 = .379) \) in L2 reading comprehension, followed
by the breadth knowledge of vocabulary with 7.6% additional variance (Table 8).
Apparently, working memory capacity was a more direct predictor of L2 reading
comprehension above other variables for advanced learners of English. Such results partly
support findings of previous studies which have reported a meaningful relationship
between working memory span and L2 reading comprehension ability of advanced leaners
However, since working memory span was treated as a single variable in the previous
studies, caution is required in interpreting these results.

Further, the results of the present study are not in line with findings from the study by
Choi (2013), who also examined the relative contribution of working memory span to L2
reading comprehension compared to L2 vocabulary knowledge. In his study, working
memory span along with text-specific vocabulary knowledge accounted for 21.7% of the
variance in literal reading comprehension ability. However, text-specific vocabulary
knowledge was found to be the only variable that explained the inferential reading
comprehension ability of EFL learners; hence, L2 vocabulary knowledge was found to be a
stronger predictor than working memory capacity for L2 reading comprehension ability of
advanced learners of English. One possible explanation for these contradictory findings
could be the different types of vocabulary knowledge tests and scoring systems used in the
studies. In Choi’s study (2013), text-specific vocabulary knowledge was assessed in the
participants’ native language, which was Korean. On the other hand, the general
vocabulary knowledge of the participants was measured in two different types of
vocabulary tests in the present study. In fact, the different types of vocabulary tests used in
the two studies, the text-specific vocabulary knowledge test and the general vocabulary
knowledge test, can yield different results.

The scoring system used in both studies also needs to be addressed in order to
understand the gap in the outcomes. In Choi’s study (2013), after each sentence stimulus, a
capitalized consonant letter was presented on the screen, which was to be recalled;
consequently, the number of correctly recalled consonant letters represented the total score
of the reading span task. In the present study, however, the composite score of the reading
span task was used which included the average of the z-scores of the number of correctly recalled final words, the number of correctly judged sentences and the mean reaction time. Such a different methodological approach could account for the disparate results.

The results that indicate the difference in the relative contribution from working memory span for each group can possibly be explained based on the findings from previous studies conducted on native speakers of English. The studies of L1 reading research reported that working memory capacity was the strongest predictor for reading comprehension above other variables for native speakers of English (Cain et al., 2004; Seigneuric & Ehrlich, 2005). Further, Seigneuric and Ehrlich (2005), who examined developmental changes of the contribution from working memory span to L1 reading comprehension through a longitudinal study, explained that vocabulary knowledge was a stronger predictor in early grade levels; working memory capacity emerged as a significant predictor in later grades. Similarly, in light of this explanation, working memory span may not be a significant predictor for less proficient learners of English; however, it comes to play a greater role for L2 learners of English as they become more competent users of English. Once L2 learners attain a certain level of L2 proficiency, the role of cognitive resources such as working memory may become more prominent. However, as the issue of potential differences in contribution made by working memory span to L2 reading comprehension ability according to participants’ proficiency levels was first addressed in this study, further research is definitely needed to draw a firm conclusion.

In the current study, L2 working memory capacity along with other variables such as L2 vocabulary knowledge and L2 grammatical knowledge was found to be a potential predictor of L2 reading performance. Thus, in future studies, it could be more interesting to examine whether these variables which are hypothesized to influence L2 reading performance interact with each other, whether they have indirect or direct relationship with L2 reading ability, and to what degree they contribute to the reading comprehension ability of L2 learners at different proficiency levels.

In spite of the informative outcome of the present study, it is not without its limitations. The main problem lies in methodological issue. In fact, the participants’ working memory span was measured using the reading span task in the study. However, the reading span task, which requires the participants to read aloud a series of sentence and then to recall the final words, may yield biased results, since the advanced learners of English can benefit from such a task (Yuill et al., 1989). Thus, including an additional working memory span measure is recommended, which could uncover differences in working memory capacity of individuals independently of linguistic ability. In future studies, along with the reading span task, using other types of working memory span measures such as the operation span task (Turner & Engle, 1989), which incorporates the arithmetic operations instead of a series of sentence to measure learners’ working memory capacity, is recommended to.
ensure criterion validity.

Another issue that can be addressed in future studies regards reading comprehension processes, including both lower-level processes (i.e., decoding, word identification) and higher-level processes (i.e., inferencing, integration skills). It would be interesting to examine how working memory interacts with lower- and higher-level reading processes, and furthermore, how they are related to L2 reading comprehension ability.

6. CONCLUSION

The results of the current study attempt to extend the scope of existing findings from previous studies in order to further understand the possible role of working memory capacity in L2 reading comprehension. An analysis of individual differences in working memory capacity seems to be one method to determine a prospective indicator of failure to reach average levels of attainment for students in L2 reading comprehension. A clearer understanding of possible reasons for reading difficulties is paramount for designing theoretical reading models as well as instructional models which could help L2 learners become more competent L2 readers (Juffs & Harrington, 2011; Oh, 2011).

Future research might attempt to examine whether the relative contribution of working memory capacity compared to other well-established predictors of L2 reading comprehension can change over time through a longitudinal study, as there has been growing evidence that working memory capacity may be subject to be strengthened by practice (Van den Noort, Bosch, & Hugdahl, 2006). In-depth research on the role of working memory capacity in L2 reading will hopefully pave the way for developing interventions which could help learners to increase their working memory capacity (Shipstead, Redick, & Engle, 2012), especially in light of the fact that working memory capacity is “a dynamic construct that reflects the learner’s knowledge, organization and experience, rather than a relatively fixed individual trait” (Juffs & Harrington, 2011, p. 157).

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Linderholm, T., & van den Broek, P. (2002). The effects of reading purpose and working memory capacity on the processing of expository text. *Journal of Educational Psychology, 94*, 778-784.


Oh, E.-J. (2011). A review on a construct of working memory and its role in L1 and L2


**APPENDIX A**

A Sample of the Reading Span Task

<table>
<thead>
<tr>
<th>Level 2: 2 sentences</th>
<th>The bus was packed with young students returning home after school.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3: 3 sentences</td>
<td><em>There was an old man who was not able to find his seat.</em></td>
</tr>
<tr>
<td></td>
<td><em>She likes to have a ham and cheese sandwich for lunch.</em></td>
</tr>
<tr>
<td></td>
<td>He opened the bottom drawer and pulled out his blue shirt.</td>
</tr>
</tbody>
</table>

*Note. *incorrect sentences

**APPENDIX B**

A Sample of the Test for Depth Knowledge of Vocabulary

<table>
<thead>
<tr>
<th>sound</th>
<th>(a) logical</th>
<th>(e) snow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(b) healthy</td>
<td>(f) temperature</td>
</tr>
<tr>
<td></td>
<td>(c) bold</td>
<td>(g) sleep</td>
</tr>
<tr>
<td></td>
<td>(d) solid</td>
<td>(h) dance</td>
</tr>
</tbody>
</table>

A Sample of Test for Breadth Knowledge of Vocabulary

1. copy ___ end or highest point
2. event ___ this moves a car
3. motor ___ thing made to be like another
4. pity
5. profit
6. tip

A Sample of the Test for Grammatical Knowledge

1. *Both his mother and his father is French.*
2. He suggested that the plan be changed.

*Note. *incorrect sentence
The Alaska pipeline starts at the frozen edge of the Arctic Ocean. It stretches southward across the largest and northernmost state in the United States, ending at a remote ice-free seaport village nearly 800 miles from where it begins. It is massive in size and extremely complicated to operate.

The steel pipe crosses windswept plains and endless miles of delicate tundra that tops the frozen ground. It weaves through crooked canyons, climbs sheer mountains, plunges over rocky crags, makes its way through thick forests, and passes over or under hundreds of rivers and streams. The pipe is 4 feet in diameter, and up to 2 million barrels (or 84 million gallons) of crude oil can be pumped through it daily.

Resting on H-shaped steel racks called "bents," long sections of the pipeline follow a zigzag course high above the frozen earth. Other long sections drop out of sight beneath spongy or rocky ground and return to the surface later on. The pattern of the pipeline's up-and-down route is determined by the often harsh demands of the arctic and subarctic climate, the tortuous lay of the land, and the varied compositions of soil, rock, or permafrost (permanently frozen ground). A little more than half of the pipeline is elevated above the ground. The remainder is buried anywhere from 3 to 12 feet, depending largely upon the type of terrain and the properties of the soil.

One of the largest in the world, the pipeline cost approximately $8 billion and is by far the biggest and most expensive construction project ever undertaken by private industry. In fact, no single business could raise that much money, so 8 major oil companies formed a consortium in order to share the costs. Each company controlled oil rights to particular shares of land in the oil fields and paid into the pipeline-construction fund according to the size of its holdings. Today, despite enormous problems of climate, supply shortages, equipment breakdowns, labor disagreements, treacherous terrain, a certain amount of mismanagement, and even theft, the Alaska pipeline has been completed and is operating.

1. The passage primarily discusses the pipeline's
   ① operating costs
   ② employees
   ③ consumers
   ④ construction

2. The author mentions all of the following as important in determining the pipeline's route EXCEPT the
   ① climate
   ② lay of the land itself
   ③ local vegetation
   ④ kind of soil and rock
A Sample of L1 Reading Comprehension Test (Korean)

1. A Sample of L1 Reading Comprehension Test (Korean)

2. A Sample of L1 Reading Comprehension Test (Korean)
Applicable levels: college

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Received in December 2013
Reviewed in January 2014
Revised version received in February 2014