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The Effects of Syntactic Enhancement on L2 Readers With Low Working Memory*

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This study investigated whether the effects of syntactic enhancement on rapid and accurate reading varies depending on second language (L2) students' working memory capacity. Visual-syntactic text formatting (VSTF) technology was used to create syntactic enhancement, reformatting text in a way to make English sentence structures salient. L2 college students from the U.S. and South Korea participated in this study. The participants were identical in terms of their baseline English proficiency, evidenced by the results of vocabulary and word recognition tests. They were assigned either to low (n = 28) or high working memory groups (n = 30) based on their scores on a working memory test. Both groups read half of the passages in the VSTF condition and the others in the block condition. Syntactic enhancement did not commonly influence the reading speed, but both groups' performance on information questions. In addition, syntactic enhancement assisted the low working memory group in making inferences. Although syntactic cues are only part of a multifaceted L2 reading process, these findings provide support for syntactic enhancement as a helpful tool to promote L2 reading comprehension without hindering reading speed, especially for those with low working memory capacity.

[syntactic enhancement/L2 reading comprehension/fluency/working memory/ 통사입력강화/제2언어독해/유창성/작동기억]

* This study is part of the author's doctoral dissertation.

I. INTRODUCTION

Becoming a proficient second language (L2) reader involves developing automaticity in retrieval of text's linguistic information, such as lexical representations and syntactic patterns (Skehan & Floster, 2002). L2 readers are much less likely to use syntactic cues compared to first language (L1) readers (VanPatten, 2004). Due to L2 readers' not-yet automatized linguistic knowledge, reading processing consumes a considerable amount of their cognitive capacity (e.g., working memory), which is inherently limited in storing and processing information and therefore results in inhibited proficient language comprehension (VanPatten, 2004). Chunking as an associative learning mechanism can not only reduce readers' cognitive load but also improve L2 reading in contexts that require substantial information processing capacity (Ellis, 2003).

From the beginning of learning a new language, we learn to chunk sounds, letters, words, phrases, and more (Ellis, 2003). Along the way, we need to repeatedly encounter a countless number of syntactic constructions from both oral and written discourses until we abstract regularities from those streams of linguistic input. Given that the small absolute amount of exposure to L2 input, both oral and written, and especially in a foreign language learning context, is very low, enhancing syntactic knowledge seems exceptionally challenging.

In a digital era, a number of technological solutions have been developed to teach L2 knowledge. These tools typically focus on teaching discrete grammatical items without reference to the setting in which they occur. This study aims to explore a way of using technology that provides a rich source of syntactic cues during real-time reading in order to assist rapid and accurate L2 reading, especially by lowering working memory load.

II. LITERATURE REVIEW

1. Working Memory and Reading Comprehension

Reading comprehension is the process of constructing mental structures in reader's mind (Gernsbacher, 1997). This human activity is subject to various inherent constraints on human cognitive capacity, for example, working memory (Carretti, Borella, Cornoldi, & De Beni, 2009). Working memory is generally defined as a storage system involved in the maintenance and manipulation of goal-relevant information (Engle, 2002). This human capacity depends on how one holds information in one's mind despite potentially interfering distractions (Jarrold & Towse, 2006).

Recent working memory models (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000) have suggested multiple executive functions of attention regulation, such as inhibition, mental set shifting, self-monitoring, and updating. Studies found that a single working memory component (storage or processing alone) does not predict L2 comprehension; instead, the composite working memory capacity does (e.g., J. Joh, 2015). The following paragraphs further detail the relationship between working memory and syntactic awareness in the process of reading comprehension.

1) The Importance of Working Memory in Reading Comprehension

It is well documented that skilled readers tend to have higher working memory capacity than do less skilled readers (Cain, Oakhill, & Bryant, 2004; Swanson & O'Connor, 2009). A number of studies suggested that individuals with greater working memory capacity tend to hold more information relevant to a current task (Swanson & O'Connor, 2009; van Leeuwen, van den Berg, Hoekstra, & Boomsma, 2007). For example, the pieces of information retained in a reader's consciousness can help one with anaphora or cataphora resolution. When reading a pronoun, a reader with high working memory capacity tends to recall the noun to which the pronoun refers.

Another line of research has shown that high capacity readers inhibit irrelevant information such that they store less information than low capacity readers (Kane, Conway, Hmabrick, & Engle, 2007; St Clair-Thompson & Gathercole, 2006). This implies that readers with high working memory are more likely to suppress the new information if it is irrelevant to a structure that they are currently building. They then shift to a new substructure in the process.

Research supports that high capacity readers can generate more inferences while reading than low capacity readers (Cain et al., 2004). An inference can be defined as information that is implicit in the text but that can be made by connecting two or more pieces of information (Elbro & Buch-Iversen, 2013). Inference-making can be as simple as solving anaphora resolutions or as complex as drawing on world knowledge. High capacity readers simultaneously retain multiple cohesive information blocks in working memory, serving as resources that allow them to construct more inferential relationships of a given story, such as identifying (in)consistencies in a text (e.g., Carretti, Cornoldi, De Beni, & Romano, 2005). The suppression mechanism may be helpful in this higher order cognitive process as well. High capacity readers have less irrelevant information in memory than low capacity readers, information which would otherwise compete for working memory resources and disrupt inference making processes (McNamara & O'Reillly, 2009).

2) Working Memory in L2 Reading Comprehension

L2 readers are possibly faced with an extra load on working memory during L2 processing, as L2 language process exerts a greater demand on the processing and storing capacity of working memory than L1 processing (VanPatten, 2004). The reason for this particular challenge involved in L2 reading can be found in information processing theories. According to information processing models that explain how information is stored and processed in the human mind, learners can attend to and process only a limited amount of information at a time, due to limited working memory (Baddeley, 2003). Sometimes learners do not need to pay much attention or make much effort to process information, whereas other times, they are consciously aware of other processes that require a substantial number of resources. Depending on the amount of attention and effort that a process requires, the process can be controlled or automatic. Controlled processes make considerable demands on cognitive capacity and require more resources, while automatic processes are unintentional and relatively effortless with little need for processing energy. From this information processing view of language, L2 researchers asserted that L2 acquisition requires more controlled processes that exert a greater demand on the processing capacity of working memory, because L2 learners may have little proceduralized linguistic knowledge (Loewen, 2005).

2. Syntactic Awareness for Reading

Syntactic awareness is an ability to phrase text into syntactically meaningful multi-word units, which helps readers understand how words, phrases, and clauses fit together in sentences to convey meaning, anticipate what comes next, and thereby avoid confusion. The extraction of syntactic information of words or word groups is essential for the construction of meaning from text (Grabe, 2009). Considering that chunking (i.e., grouping of several single units into a meaningful compound element) is a common learning strategy to increase the efficiency of working memory (Cowan, 2012), it seems reasonable to conjecture that high capacity readers effectively store and process incoming language items by chunking them.

Though an inference-making ability in large part depends on varying degrees of one's knowledge structure (Elbro & Buch-Iversen, 2013), syntactic cues in text can also play a role in this higher level of information processing. According to Givón (2009), surface information of text, including syntactic cues, does not survive beyond one's working memory; however, this information assists readers in placing chunks, with which the information is associated, in a coherent structure—a hierarchical and sequenced representation of text. This associatively structured network of text can make information be more readily available for later retrieval. Givón added that a current context cues the retrieval of stored information. Although he did not directly address the role of syntactic information of current text in the old information retrieval, one may take this explanation as an implication that syntactic sources in the given context can make it easy to access and recollect the stored information for making inferences.

Kintsch (1995) agreed with Givón that syntax plays a role of mental process instruction in comprehension processes. He argued that due to limited working memory capacity, all of the information cannot always remain activated; instead, readers experience recurring processes of analyzing, storing, and connecting pieces of chunks from text. Syntactic cues usher readers through this processing, telling them specifically where to search for what in a specific text (e.g., subject-verb-object construction, cues for topicality, etc.). It is in this way that although sophisticated levels of comprehension cannot be completed without full knowledge (e.g., vocabulary, prior knowledge, etc.) about a given text, syntactic cues can expedite the readers' processing toward high levels of comprehension, such as inferences (Kintsch, 1995).

3. Enhancing Syntactic Awareness: Syntactic Enhancement

Despite aforementioned adverse factors, syntactic awareness needs to be meticulously developed for effective L2 structure building processes. In this sense, VanPatten (2004) early on suggested that L2 reading instruction should be designed in a manner that discourages readers from solely relying on meaning-based cues and from ignoring syntactic cues. Teaching how to chunk isolated pieces of words into meaningful phrases can be a useful instructional strategy, as a way to reduce working memory load and to facilitate the reading mechanisms. In fact, studies on the cognitive process have demonstrated that meaningful unit-based chunking of information has beneficial effects on learning, either by reducing repeated attention-switching between old and new information (Barrouillet & Camos, 2007) or by reducing the cognitive load that learners need to identify salient boundaries between information units (Wouters, Paas, & van Merriënboer, 2008). However, chunking as a reading strategy is insufficient in providing learners with abilities to capture hierarchical syntactic structure. From an instructional perspective, it is time consuming and uneconomical to teach how to parse sentences while students are reading. The following section turns its attention to the use of technology to address such issues.

Input enhancement, one of common L2 teaching strategies, is manipulating texts in a manner to make the target input more salient in order to positively affect the learning process of L2 students and thereby increase their language awareness (Smith, 1991). Input enhancement has been identified as an effective instructional strategy in Korea (e.g., S. Y. Hwang, 2005). This study employed visual-syntactic text formatting (VSTF) which is automatic natural language parsing and text presentation technology, in order to make syntactic structure salient for L2 readers (see Figure 1). This technology is accessible at www.liveink.com.

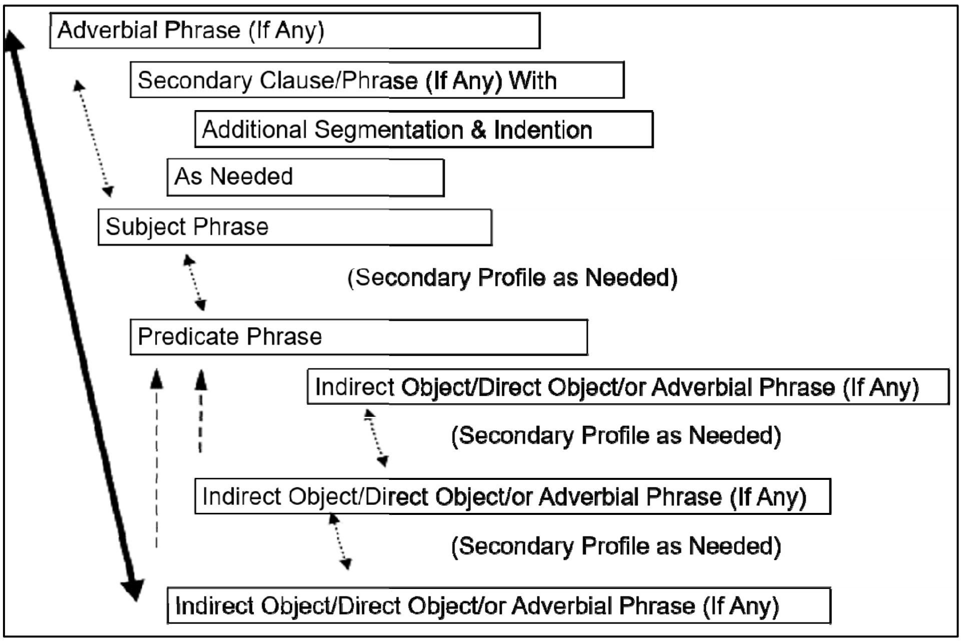

FIGURE 1 How VSTF Technology Segments Sentences and Differentiate Indentations by Using Lexical and Special Criteria (Walker & Vogel, 2005)

Studies conducted in and outside Korea have suggested that VSTF can scaffold L2 reading by easing eye movement (Walker, Schloss, Fletcher, Vogel, & Walker, 2005), increasing struggling readers' confidence (Y. Park & Warschauer, 2016), drawing readers' attention to syntactic knowledge (S. A. Lee & J. B. Yu, 2013; R. Oh, Y. Park, & H. K. Lee, 2016; Y. Park & Warschauer, 2016) or prosodic cues (Y. Park & Warschauer, 2016), increasing reading speed (Y. Park & Warschauer, 2016), assisting their understanding of text (R. Oh, Y. Park, & H. K. Lee, 2016; Walker & Vogel, 2005), and helping their retention (Walker & Vogel, 2005).

Most of these studies hypothesized the potential influence of phrase-segmented format on readers' working memory, but did not test this influence. In addition, there are contradicting reports regarding reading speed as compared to regular block formatted reading. Therefore, this study aimed to answer the following research questions:

1) Are the effects of syntactic enhancement on L2 reading speed moderated by L2 readers' working memory capacity?
2) Are the effects of syntactic enhancement on L2 reading comprehension moderated by L2 readers' working memory capacity?

III. METHOD

1. Design

This study employed a two-way mixed design. This research design included a within-subjects factor of *text format types* (block-formatted or phrase-segmented), a between-subjects factor of groups (*working memory*—High, Low), and covariates of baseline English proficiency scores. In order to divide participating students into low- and high-working memory capacity levels, a complex span task, which is explained in the following section, was used.

2. Participants

This study constitutes a secondary analysis of a subsample drawn from a larger study. A total of 110 L1 (n = 33) and L2 students (n = 77) from the U.S. and Korea participated in the primary study. In the current study with the focus on L2 reading, data from 58 L2 students both from Korea (n = 28) and the U.S. (n = 30) were used for analyses after removing outliers.

To learn about participants' learning profiles, I modified and used the Language History Questionnaire (LHQ) (Li, Sepanski & Zhao, 2006). Korean students' responses confirmed that they had similar learning experiences in terms of instruction time at school and little use of English outside the classroom. Most of the participants had never been to English speaking countries (91.7%), and even those who had experience abroad spent less than one year in English speaking countries (8.3%). As for the students from the U.S., the number of years they lived in the U.S. ranged from 1 to 10 years. The majority of them were native speakers of Chinese (39%), followed by Spanish (14.6%) and other languages (Farsi, Vietnamese, Korean, Dutch, and Konkani).

3. Apparatus

Once passages and comprehension questions were selected, VSTF technology was used to convert block-formatted reading passages (on the left in Figure 2) into phrase-segmented passages (on the right in Figure 2).

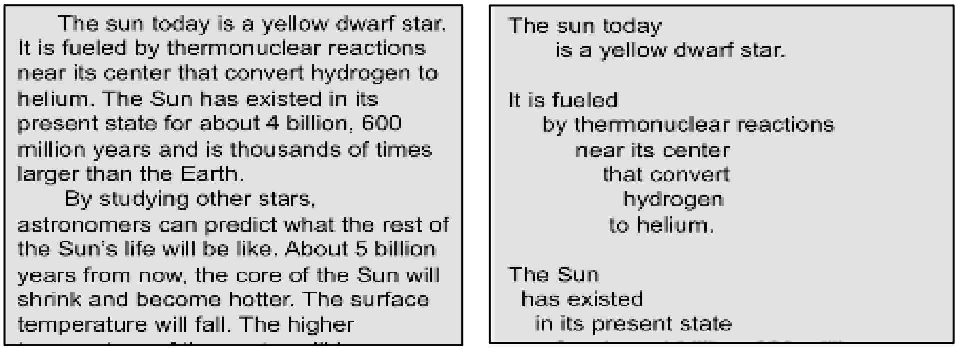

FIGURE 2 Screenshots of Reading Passages

Each passage (both block and phrase-segmented) was arranged in three columns to fit on one page. Passages were each saved as a separate image file with words in black Arial MS 18pt font size against an alternating white and grey background. Each comprehension question was also prepared as a separate image file. Words were black Arial MS 24pt font size against a white background.

4. Measures

1) Between-Subjects Factor: Working Memory Capacity

Symmetry span task with spatial locations as a to-be-remembered item, developed by Shah and Miyake (1996), was chosen to measure participants' working memory functioning for two reasons. As shown in Figure 3, this task does not require English skills to ensure that participants' performance in this task would not be significantly confounded by their language ability. This is especially important for L2 English speakers whose English proficiency might be otherwise reflected in their scores on other tasks (e.g., verbal) rather than working memory capacity that needed to be measured.

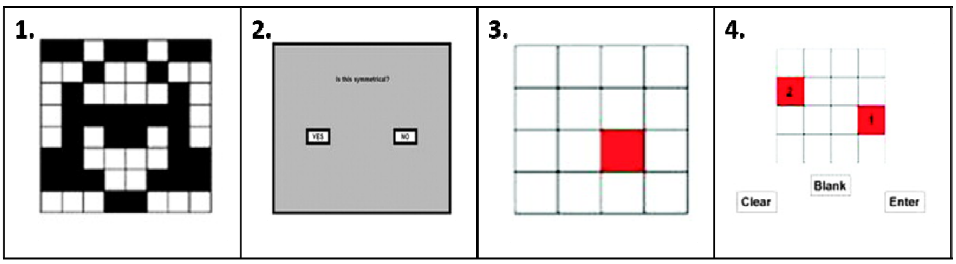

FIGURE 3 Example of a Sequence of Tasks in the Working Memory Measure

For each trial in the computerized symmetry span task, participants were asked to judge whether a given pattern was symmetry (i.e., processing task) and to simultaneously recall sequences of red squares within a matrix (i.e., storage task). For the processing task participants were presented with an 8 × 8 matrix with some squares in black and others in white. They were required to decide whether the black pattern was symmetrical along its vertical axis. For the storage task participants saw a 4 × 4 matrix with one of the cells filled in red, presented for 650 ms. They were asked to recall correct sequences of red squares within a matrix by clicking on the cells of an empty matrix. After three practice conditions—storage task only, processing task only, and interleaved tasks, participants were processed to the actual trials. Individualized time limits were calculated during the processing task only session (the participant's mean plus 2.5 *SD*) and used as the maximum processing time during the processing and storage task sessions. The score was the number of correct items recalled in the correct position and processing time. The test-retest reliability was reported to be high somewhere else (.77 in Unsworth, Heitz, Schrock, & Engle, 2005; .80 in Unsworth, Redick, Heitz, Broadway, & Engle, 2009). Tasks in the working memory measure were programmed and administered using E-Prime (Schneider, Eschman, & Zuccolotto, 2002) experimental software.

2) Baseline Reading Proficiency Measures: Vocabulary and Word Recognition

A reading proficiency measure, which was developed to assess reading proficiency of both native and non-native students (Abedi, Courtney, & Leon, 2003), was used to provide an indicator of each participant's current English reading proficiency level in this study. This proficiency test consisted of two subtests: vocabulary (10 items) and word recognition (75 items) tests. This test was an internally consistent instrument, as evidenced by the Cronbach's alpha (.84).

Psychopy (Peirce, 2007), an open-source software package, was used to program and run this test. One item represented each stimulus; that is, one stimulus (one question) was presented at a time. All stimuli were horizontally and vertically centered and presented in black against a white background. Question items appeared in a random order for each participant. It is reported that Psychopy has sub-millisecond precision with a latency of 4-25 ms depending on platforms and keyboards.

3) Experimental Reading Measures: Reading Comprehension and Speed

(1) Reading Comprehension Test

Reading passages for reading assessments were obtained from the reading comprehension section of a test-preparation book for the Test of English as a Foreign Language (TOEFL, Rogers, 2001). The number of words per passage ranged from 179 to 370 ($M = 252$, $SD = 62$). Readability scores ranged from moderate difficulty (7.3 to 9.9) to difficulty levels (10.1 and 13.6).

Guided by research on comprehension tasks (Raphael & Au, 2005), comprehension questions included topic, vocabulary, basic recall, and inference-making. All of these questions were multiple-choice questions with four potential answers. Each correct answer was awarded one point. Raw scores were converted into percentage scores to allow easy comparisons.

The comprehension test was an internally consistent and valid instrument. Reliability was assessed by the Cronbach's alpha (.76). The construct validity of comprehension questions was evaluated from a confirmatory factor analysis with one factor and the standardized root mean squared residual (SRMR) index (ranging .05 to .07). Guided by Hu and Bentler (1999), this result indicates that all of the items within each question type were linked to a unique underlying factor, implying good construct validity.

Psychopy (Peirce, 2007) was also used to program and run the reading test. Either a passage or a comprehension question represented each stimulus. Each passage fit one page such that there was no need for the participants to scroll or advance to a next page. Participants were able to stay on screen with a passage until they were ready to answer comprehension questions. Once ready, participants pressed any key to advance to the next screen with a question. Then they pressed a number key, 1 to 4, corresponding to the answer they thought correct to a multiple-choice question.

One important determinant of this study is text accessibility while participants were answering each question. Text was not displayed during the question-answering process in order not to allow participants to use skills that were not intended to be assessed in this study (e.g., information search skills). More importantly, when solving comprehension questions without text access participants are more likely to use their working memory capacity (Ozuru, Best, Bell, Witherspoon, & McNamara, 2007) and inference-making skills (Schaffner & Schiefele, 2013).

(2) Reading Speed

The programmed test recorded response time to each stimulus (i.e., how long it took a participant to respond after a stimulus was presented on a screen) in milliseconds. Using this reaction time data, silent reading speed was calculated in words per minute (WPM) based on the formula: WPM = (the number of words in a passage / reading time in seconds) × 60. The total time spent on each passage was automatically recorded by Psychopy at the millisecond level and available in a spreadsheet for analysis at the end of the trial.

5. Procedures

The testing session included working memory, reading proficiency, and experimental reading tests, lasting approximately 75 minutes. Participants were allowed to take breaks between successive tests if they wished. The working memory test was first administered. Participants then took the baseline proficiency test. The experimental reading test session consisted of a practice session and an actual test. The practice session, which had eight sample passages in phrase-segmented format with comprehension questions, was aimed at ensuring that participants became familiar with the phrase-segmented format as well as the testing environment. When ready for the actual test, participants were allowed to skip the rest of the sample passages. The actual test had eight passages: four of them in phrase-segmented format and the rest in block format. Both the format type of each passage and the order of text presentation were randomized. Immediately following each passage, participants answered five multiple-choice questions. The order of question presentation was also randomized. Participants were not allowed to go back to passages while answering questions.

IV. RESULTS

1. Data Analysis

For the hypothesis testing, the participants were assigned to high and low capacity groups based on their scores on the working memory measure. Their scores ranged from 20 to 53 with a median (41.41) split grouping factor. As a result, 28 students (12 Korean and 16 U.S.-based students) were assigned to the low working memory capacity group and the remaining 30 (16 Korean and 14 U.S.-based students) to the high capacity group. Mean working memory score of high working memory group (M = 47.14, SD = 3.27) is different from that of low working memory group (M = 35.98, SD = 4.83) at a significance level of 0.05. However, working memory scores of Korean participants (M = 43.05, SD = 6.56) and American participants (M = 40.53, SD = 7.17) who remained in this analysis were not significantly different from each other.

2. Findings

Table 1 shows descriptive statistics of baseline reading proficiency measures by group. There was no group difference found on both of the tests, as proved by t-test results (vocabulary: $t(56) = 1.64$, $p = .11$; word recognition: $t(56) = .11$, $p = .91$).

TABLE 1
Descriptive Statistics of Vocabulary and Word Recognition Tests by Group

	Vocabulary				Word Recognition			
	Min	*Max*	*M*	*SD*	*Min*	*Max*	*M*	*SD*
Low WM Group ($n = 28$)	6	10	8.25	1.21	50	71	60.61	5.02
High WM Group ($n = 30$)	4	10	7.70	1.34	50	71	60.66	5.56

1) The Effects of Syntactic Enhancement on L2 Reading Speed

Reading speed and comprehension data from 58 L2 students were analyzed to answer research question 3. The between-subjects factor in this analysis is participants' working memory capacity level. As described in the Data Analysis section, high ($n = 30$) and low ($n = 28$) working memory groups were compared in terms of their reading performance. These two groups are hereafter referred to as high and low WM groups.

Reading speed was analyzed using a two-way mixed GLM with format as within-subjects factor and working memory group as between-subjects factor. This model included the same covariates—vocabulary and word recognition scores. This analysis sought out reading speed changes as a function of text format types for each level of the group.

The analysis result showed that the main within-subjects effect was not significantly different on combined dependent variables ($F(4, 51) = .65$; $p = .63$, Pillai's Trace = .05; partial $\eta^2 = .02$) nor was the interaction ($F(4, 51) = .17$; $p = .95$, Pillai's Trace = .01; partial $\eta^2 = .02$). These results implied that text format types did not affect reading speed for either group.

With regard to between-subjects factors, no significant difference was found across groups ($F(4, 51) = 0.65$; $p = .16$, Pillai's Trace = .12; partial $\eta^2 = .12$). These data did not provide evidence of the association between reading speed and working memory capacity.

2) The Effects of Syntactic Enhancement on L2 Reading Comprehension

A two-way mixed GLM was also conducted to understand the effects of text format types (block, phrase-segmented) and working memory capacity (high, low) on reading comprehension. This analysis included the same within- and between-subjects factors and covariates as in the analysis above of reading speed. Figure 4 displays overall within- and between-group differences on comprehension tests.

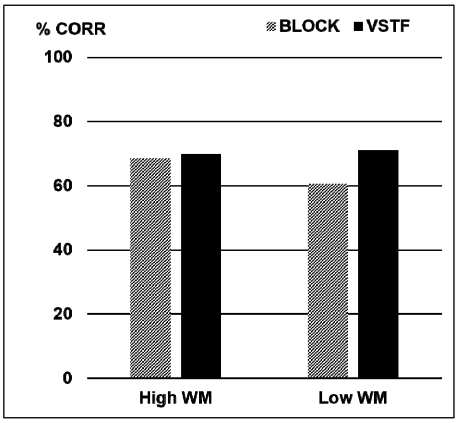

FIGURE 4 Adjusted Means of Overall Reading Comprehension Scores

The main effect of format was statistically significant ($F(4, 51) = 3.60$; $p = .01$, Wilks' Lambda = .78; partial $\eta^2 = .22$). The two-way interaction was also significant ($F(4, 51) = 2.66$; $p = .04$, Wilks' Lambda = .83; partial $\eta^2 = .17$). The group difference, however, was not significant ($F(4, 51) = 0.79$; $p = .54$, Wilks' Lambda = .94; partial $\eta^2 = .06$).

Follow-up ANOVAs identified which dependent variables had significant differences. In particular, the effect of format types on topic and information questions was significant to a similar extent for both working memory groups. This is evidenced by a significant main effect (topic: $F(1, 54) = 3.32$, $p = .07$, partial $\eta^2 = .05$) and a non-significant interaction. Text format types affected vocabulary and inference-making questions differently for high and low working memory groups. This is suggested by a significant interaction on inference-making ($F(1, 54) = 3.24$, $p = .04$, partial $\eta^2 = .07$).

In order to further investigate the differences, all pairwise comparisons with Bonferroni corrections were performed for statistical significant simple main effects. Figure 5 illustrates these differences in terms of adjusted means and standard errors. No significant group difference was detected across format types.

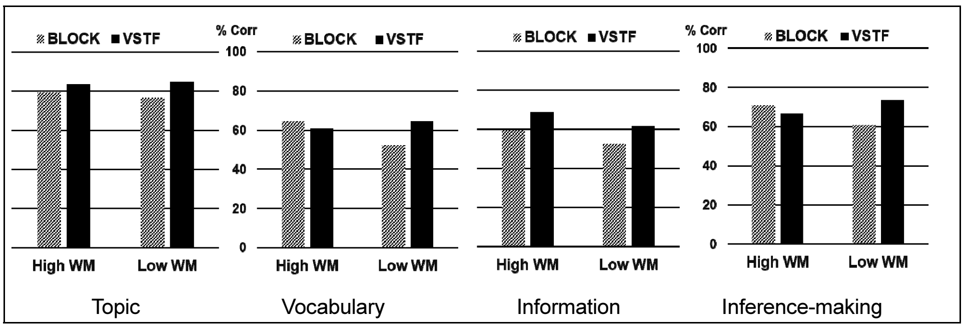

FIGURE 5 Adjusted Means of Reading Comprehension Scores

With regard to the within-group differences, students from both working memory groups scored higher in phrase-segmented format than in the other condition on topic and information questions. A significant difference, however, was only found in information questions (High: $M = 9.31$, $SE = 4.13$, $p = .03$; Low: $M = 9.22$, $SE = 4.29$, $p = .04$). The two groups showed different patterns on vocabulary and inference-making questions: the high WM group scored higher in block condition than the other while the low WM group produced the opposite pattern of results. The within-group difference in the high WM group was not significant. The low WM group had a statistical significance in inference-making questions ($M = 12.76$, $SE = 5.9$, $p = .04$).

V. DISCUSSION

The research questions were concerned with how L2 readers respond to the phrase-segmented text format depending on their working memory capacities. The questions aimed at delving into the format effects on reading speed and comprehension in relation to participants' working memory span.

It was found that the two groups were basically equivalent not only on baseline proficiency but also on experimental assessments of reading speed and comprehension. In both groups alike, the phrase-segmented format did not affect reading speed but did facilitate reading comprehension. The two groups, however, responded differently to the text format types in comprehension tests. In particular, both groups performed better on topic and information questions when reading phrase-segmented passages than block passages. A statistically significant difference was found only in information questions. Diverging patterns across groups were observed in inference-making and vocabulary questions. When reading phrase-segmented text, the low capacity group gained significantly higher scores in inference making questions and slightly higher scores in vocabulary questions. The opposite patterns were observed among the high capacity group but with no statistical significance.

The finding of no group difference across text format appears to contradict the observations from previous studies in which skilled readers tend to have higher working memory capacity than less skilled readers (e.g., Swanson & O'Connor, 2009). This speculation may also explain the absence of significant group difference in the phrase-segmented condition. In spite of this absence, it is important to take into account a small but critical difference that was found in inference-making and vocabulary questions. This result clearly suggests that the phrase-segmented format reading contributed to a high level of text comprehension that L2 readers, especially those with inefficient working memory function, find challenging.

The outcome of the low capacity group in the phrase-segmented condition supports the previous studies on the correlation between working memory capacities and inference-generation abilities (e.g., Cain et al., 2004). This association between working memory and high-level comprehension skill can be elucidated in relation to the enhancement and suppression mechanisms within Gernsbacher's (1997) structure building model. Individuals with greater working memory capacity tend to store and process information effectively by holding more of the relevant information (Swanson & O'Connor, 2009) and less of the irrelevant information (McNamara & O'Reillly, 2009). Resourceful working memory skills through effective enhancement and suppression mechanisms subsequently enable readers to generate inferences during reading.

In this inference making process, the hierarchically segmented text format can help L2 readers with low working memory capacity for the following reasons. According to Givón (2009) and Kintsch (1995), syntactic information serves as guidance in the structure building process of comprehension. Syntactic processing, in which readers process linear arranged sentences from left to right and transform them to a hierarchical structure (Hurford, 2011), may result in working memory overload (Frank, Bod, & Christiansen, 2012). This problem becomes worse for L2 readers because L2 reading processing entails controlled information processing that inherently involves great demand on working memory capacity (VanPatten, 2004). For L2 readers to develop from this controlled processing to automatic processing is excessively demanding (VanPatten, 2004). In this bootstrapping process, it makes little sense to improve syntactic knowledge through reading without an adequate amount of syntactic knowledge in the first place. Reading already-parsed text in a hierarchical manner consequently helps comprehension of L2 readers who do not have high working memory capacity and extensive amounts of syntactic knowledge.

My claim about the relationship between text format and working memory function is particularly validated by the testing environment of this study. That is, reading passages were not available when the participants were answering the questions, as suggested by Schaffner and Schiefele (2013). If the passages had been made available to the readers, as they were in other studies (e.g., Oakhill, 1984), one would have casted doubt on readers' performance on inference questions in the phrase-segmented format condition. As McNamara and O'Reilly (2009) emphasized, readers' memory resources might be relieved to a certain degree when passages, in which answers to inference questions can be found, are made available. Therefore, in the testing condition without passages available when readers were answering questions, such as the current study, generating inferences requires a considerable amount of capacity and knowledge that enable readers to relate different parts of text and even prior knowledge. Phrase-segmented format is thought to facilitate this perplex process.

VI. CONCLUSION

This study set out to explore syntactic enhancement in L2 reading contexts and its potential relationship with readers' limited cognitive capacities. The use of syntactic enhancement as scaffolding of L2 reading is drawn from the idea of input enhancement that has been commonly used in L2 research and instruction. Input enhancement manipulates texts in a way to make target L2 input salient, which otherwise learners are likely to neglect, in order to make learning of this particular input take place. A number of L1 research, but a very few L2 studies, have examined the idea of manipulating text to make phrase boundaries noticeable. Drawing on the theoretical literature on the use of syntactic cues for enhanced comprehension, this study investigated how phrase-segmented format facilitates rapid and accurate L2 reading, especially for readers with low working memory capacity. As a tool to convert standard block text to phrase-segmented text, VSTF technology, which reformats text into hierarchically organized segmentation based on linguistic rules and human perceptual tendency, was used.

The heterogeneous effect of phrase-segmented format among two working memory groups was found only in inference-making questions. This result contributes to speculation that working memory capacity is associated with high level comprehension skills, such as inference-generation abilities. This specific association has been reported in a number of studies (Just & Carpenter, 1992; Yuill & Oakhill, 1991). Furthermore, the format effect on inference generation found in this study lends a support to accounts of Givón (2009) and Kintsch (1995) on the role of syntactic information as a guide in coherent text construction that consumes much of working memory resources.

In addition, this research provides practical implications to L2 learners, educators, and text developers. Many L2 learners who have sufficient amounts of vocabulary but limited syntactic knowledge and who easily experience working memory overload can benefit from reading hierarchically segmented text for more refined comprehension. As technology converts text format in several seconds, the phrase-segmented format is easily accessible to any teachers who would like to make use of content-related activities rather than tedious metalanguage lessons within their restricted instructional time. Text developers should consider phrase-segmented text as a viable option for reading resources in order to ease working memory load.

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Examples in: English
Applicable Languages: English
Applicable Levels: Tertiary

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