A Review on a Construct of Working Memory and Its Role in L1 and L2 Reading Comprehension

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The research on the role of working memory in L1 and L2 reading comprehension has provided valuable insight on domain-general mechanisms at work in both comprehension processes. The present paper explains a construct of working memory as a multi-component model (Baddeley, 2007; Baddeley & Hitch, 1974), reviews empirical studies that investigated the impact of working memory in L1 and L2 reading comprehension, introduces a newly adopted construct to the model of working memory, episodic buffer or long-term working memory (Ericsson & Kintsch, 1995), and discusses the role of background knowledge in relation to working memory. The review of the studies showed that central executive, an attentional control system, is a significant predictor for not only L1 reading but also L2 reading comprehension. Phonological loop, a storage system, is significantly related to central executive. However, it is not a direct significant predictor for L1 and L2 reading comprehension; instead, it explains significant variances of vocabulary acquisition in the beginning stage of language acquisition, which is a direct significant predictor for reading comprehension. How high vs. low working memory groups make use of their cognitive resources in L1 and L2 reading when provided with additional background knowledge is further discussed.

I. INTRODUCTION

What kinds of competences or abilities explain reading comprehension has been explored with various foci for research; i.e., individual differences in decoding (Abu-Rabia, 1997; Da Fontoura & Siegel, 1995; Durgunoglu et al., 1993; Gholamain & Geva, 1999; Wade-Woolley & Geva, 2000), word recognition (Adams, 1990; Ehri, 1994, 1998; Seidenberg & McClelland, 1989), retrieval of the word meanings (Barcroft, 2007; Basi, Thomas, & Wang, 1997; Gardiner, Craik, & Bleasdale, 1973), and assigning thematic roles to the words for syntactic unit formation (Abu-Rabia, 1995;
Crain & Shankweiler, 1988; Da Fontoura & Siegel, 1995; Nagy, McClure, & Mir, 1997; Verhoeven, 1990) have been explored at a surface level, whereas a role of background knowledge (Barry & Lazarte, 1995; Bugel & Buunk, 1996; Carrell & Wise, 1998; Chen & Donin, 1997; Johnson, 1982; Lee, 1986; Pulido, 2003, 2007), the use of reading strategies (Block, 1986, 1992; Jimenez, Garcia, & Pearson, 1995, 1996), individual differences in making inferences (Lee & Wolf, 1997; Nassaji, 2003, 2004) have been investigated at a higher cognitive processing level. When it comes to L2 reading comprehension, it becomes more complex due to its nature of dual-language processing, “continual interactions between the two languages as well as incessant adjustments in accommodating the disparate demands each language imposes” (Koda, 2007, p. 1). Despite the multidimensionality of the competences that explain L1 and L2 reading comprehension, one construct, working memory has come to the fore for research in the field.

Several studies (Ackerman, Beier, & Boyle, 2005; Beier & Ackerman, 2005; Conway et al., 2002; Kane, Hambrick, & Conway, 2005; Oberauer et al., 2005) showed that working memory is highly correlated with general intelligence, especially fluid intelligence that deals with novel information. This domain general nature of working memory makes it possible to understand one mechanism at work during online cognitive processes of L2 reading in the midst of various aforementioned factors at play. For this reason, it is worth reviewing literature on working memory and its relationships to L1 and L2 reading comprehension. Understanding what role working memory plays in reading and how it interacts with other important variables of reading comprehension will help clarify the nature of reading difficulties or facilities that one might encounter while engaged in reading and come up with better instructional models to address them.

Based on this rationale, the paper discusses (1) a general framework of working memory; (2) empirical studies that have shown statistically significant contributions of the working memory components to L1 and L2 reading; (3) a more recently introduced component, the episodic buffer/long-term working memory; and (4) empirical studies that explored the interplay between working memory and background knowledge for L1 and L2 reading; the effect of contextual knowledge for L1 reading and the effect of topic familiarity for L2 reading in relation to working memory. Some pedagogical implications and future directions for research are discussed in the conclusion.
II. GENERAL FRAMEWORK OF WORKING MEMORY

It appears that there is some debate over what working memory is composed of and how each component identified by a particular model functions despite a widely perceived consensus on its significance upon various cognitive processes relevant to reading (Alptekin & Ercetin, 2010; Juffs, 2004). It could be misleading to use the term, 'working memory' as one unitary entity when it is in fact a composite of several independent variables with some shared variances among them. This could be even more problematic when interpreting and synthesizing the results of various studies that have claimed that they have tested the function of working memory unless the components that have been tested and the measures that have operationalized the components of working memory are clearly defined. For this reason, it is necessary to begin with an overview of a model of working memory that has identified its multi-components together with the measures that have widely been used to operationalize each component of the model and with empirical studies that have reported evidence for the multi-component feature of working memory and its significance in reading.

The model of working memory was introduced by Baddeley and Hitch in 1974. Even though the term 'working memory' appears to have been invented by Miller, Galanter and Pribram (1960) and was used by Atkinson and Shiffrin (1968) according to Baddeley (2007), it appears that the three system model that Baddeley and Hitch (1974) presented has widely been used and remained influential in neuroscience and developmental psychology as well as cognitive psychology due to its interpretive power with empirical data (Andrade, 2001). Unlike the unitary short-term store proposed by Atkinson and Shiffrin (1968), Baddeley and Hitch characterized the model with a multi-component nature of memory in the short-term store, which is composed of an attentional control system, the central executive along with two slave storage systems, the phonological loop and the visuospatial sketchpad. They argued that all three systems were limited in capacity while having nature of differential limitations. According to Baddeley (2007, p. 7), the phonological loop is a system that holds "speech-based and possibly purely acoustic information in a temporary store, [whose]storage is assumed to be dependent on a memory trace that would fade within seconds ... [if not rehearsed] in a form of either overt or covert vocalization. The second slave system, the visuospatial sketchpad concerns visual and spatial information. Baddeley explained that the visual aspects of the system are related to patterns or objects while a spatial component is concerned with location and that it is possible to make a distinction between them. He argued that studies on brain-damaged patients and studies of normal brain function using neuroimaging techniques (Della Sala & Logie 2002; Jonides et al., 1993; Smith & Jonides 1997) provided some
evidence for multi-component of working memory rather than unitary.

The measure that has been most commonly used for phonological loop is a non-word repetition task or a serial recall task, where participants are given a digit/letter string or semantically unrelated word sequence and asked to recall the order. In order to recall the correct order of the serial or sequence, one is expected to have a better storage capacity for phonological information on hold before recall. The reading span task (RST), introduced by Deneman and Carpenter (1980) and widely used to investigate relations between working memory and reading, is assumed to tap the central executive because it involves not only a storage component but also a processing component and attentional control to inhibit or suppress irrelevant information to recall the target word (Osaka et al., 2002). In the original RST task, subjects were given a series of sentences to read aloud and then asked to recall the final word of each sentence. The reading span was the number of final words recalled correctly. In a modified version, a simple comprehension question on the sentence was inserted to secure the component of processing in the task; i.e., a sentence span task by Swanson (1992). The visuospatial sketchpad, which has been relatively less frequently tested in relation to reading, was measured using a visual matrix (Swanson, 1995), where participants were asked to remember visual sequences of dots within a matrix, and mapping directions (Swanson, 1992), where participants were to remember sequences of directions on an unlabeled map.

One study that provided evidence for the multi-component model of working memory in reading was conducted by Swanson and Howell (2001); two slave systems (the phonological loop and the visuospatial sketchpad) are independent from each other but share some variances in common for a domain general system (the central executive). Even though the focus of the study was on the independent contribution of central executive function of working memory above and beyond age-related factors, the inclusion of the three components of Baddeley’s model in their instruments made it possible to understand the nature of multi-component model of working memory. From the data of 100 fourth and ninth grade children, they analyzed scores of various WM components: 1) verbal working memory operationalized in a sentence span task and auditory digit sequencing (numerical recall task), most of which is assumed to tap the central executive; (2) short-term memory (STM), measured with digit and word span tasks (equivalent to phonological loop) and some visual activities; and 3) visual-spatial working memory (vsWM) operationalized in a visual matrix and mapping directions. The measures of reading comprehension and word recognition were used as dependent variables for various models of hierarchical regression analyses.

Of the various models that they tested, the comparison of Model5a and Model5c whose predictors included articulation speed (AS) & STM, Verbal WM, vsWM with a
different order for each model validated the multi-component nature of working memory. Model5a showed that the verbal WM (sentence span task and auditory digit sequencing) had a significant contribution to reading comprehension and word recognition after partialling out the significant effects of AS&STM. When vsWM was entered as a third variable after the verbal WM, no significant contribution of the vsWM was found; the order of the variable entry was (1) AS&STM*1- (2) verbal WM*2- (3) vsWM3 n.s.. However, when Model5c was entered, a significant contribution of the vsWM was found with a significant contribution of verbal WM as a third variable entered (1)AS&STM*- (2) vsWM*- (3) verbal WM*).

Thus, the three findings are summed up as following: (1) the shared variance between verbal WM and vsWM was significant after removing the effect of AS&STM when vsWM was entered as a second variable; (2) the portion that vsWM explains without the effect of verbal WM was not significant; and (3) the verbal WM has a significant contribution even after removing the effect that STM and vsWM together account for. To interpret the results in Baddeley’s term, the phonological loop (STM) along with articulation speed has a significant independent contribution (first entry in both models), the central executive (verbal WM) shares variances with the visuospatial sketch pad significantly (the comparison of Model5a and Model5c), the central executive has a significant independent contribution above and beyond the contribution of phonological loop and visuospatial sketch pad (Model5c), and the visuospatial sketch pad itself does not have a significant contribution after partialling out what the central executive and the phonological loop account for (Model5a). Even though the relationship between the phonological loop and the central executive was not directly tested using a hierarchical regression model, the partial correlation between verbal WM and verbal STM (phonological loop) was significant (.68* at p < .001). Thus, the results support the Baddeley’s model of three component working memory (two slave systems subjected to central executive) as a viable model to be used.

III. WORKING MEMORY AND L1 AND L2 READING

There are several studies that explored the relations between L1 reading and

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1 AS&STM stands for articulation speed and short-term memory.
2 WM stands for working memory.
3 vsWM stands for visual spatial working memory.
4 This is the correlation between verbal WM and verbal STM (phonological loop) after partialling out the effect of word recognition and articulation speed.
working memory. Using a longitudinal research design, Cain, Oakhill and Bryant (2004) assessed the progress of 102 seven- and eight-year olds in the various areas, in which individual differences for reading have been identified. Two working memory measures, sentence span task (central executive) and digit span task (phonological loop), were used to assess the children’s working memory. Using reading comprehension as a dependent variable (hierarchical multiple regression), they explored the variances that working memory (composite scores of sentence and digit span tasks) and component comprehension skills explain after controlling for word reading, vocabulary, and verbal IQ. The results showed that the combined working memory explained significant variance in reading comprehension above and beyond the contribution made by the other variables at each time point of the 8th, 9th, and 11th years. They concluded that working memory should be considered one of several factors that influence comprehension ability and comprehension development.

Concerning the interplay of two working memory span tasks, the sentence span task was more highly correlated with reading comprehension and the component skills than was the digit span task. However, significant correlations between the two working memory assessments found at each time point indicate that both of the tasks tap a common construct. This is not surprising because a sentence span task is assumed to tap a composite of the storage and processing (central executive), while a digit span task is expected to address a storage aspect of phonological loop. This is consistent with the assumption of the multi-component model of working memory that the phonological loop is independent but subject to the central executive processing system. It seems that the phonological loop alone (digit span task or non-word repetition) does not have much power to explain individual differences in reading comprehension because the digit span task was significantly correlated with other variables intermittently: significant correlations were found only at Time2 (9th year) with reading comprehension and inferencing making and at Time3 (11th year) with a vocabulary subset. Thus, an overall finding of the study is that the central executive (sentence span task) is a stronger predictor for reading than the phonological loop (digit span task).

This result of the digit span task is consistent with what Deneman and Carpenter (1980) reported. They explained that no systematic differences were found between good and poor readers who were classified on the basis of a general reading comprehension test when the standard digit span test (Guyer & Friedman, 1975; Hunt et al., 1973) or a probe digit span test (Perfetti & Goldman, 1976) were used. They also reported that letter strings (Farnham-Diggory & Gregg, 1975; Rizzo, 1939) or similar sounding words (Valtin, 1973) had been only slightly more successful as predictors of reading comprehension. However, Thorn and Gathercole (1999) fleshed
out the role of phonological loop for reading. They argued that “adequate short-term representations of the phonological forms of new words represent a critical stage in their becoming part of the permanent lexicon, and therefore that individuals with relatively poor phonological loop function are less successful in learning in the sound structure of new words,” (Thorn & Gathercole, 1999, p. 303). In other words, phonological loop can be a good predictor for reading comprehension, given that vocabulary knowledge is significantly correlated to reading comprehension.

The role of the phonological loop for reading comprehension had in fact been addressed by Gathercole et al. (1992). They explored the developmental association between phonological memory and vocabulary knowledge at children’s ages of 4, 5, 6, and 8 years. They found a significant shift in the causal underpinnings of the relationship between phonological memory and vocabulary development before and after 5 years of age. Based on the data they collected, they argued that phonological memory skills appeared to exert a direct causal influence on vocabulary acquisition between 4 and 5 years but this pattern weakened in later years because vocabulary knowledge itself took the role of the phonological memory afterwards. Although not fully disclosed, the role of phonological loop appears to play a critical role in the beginning stage of language learning; thus, phonological loop is a significant predictor for young children. This explains little significant contribution of digit span tasks to reading comprehension for adults or older children. This issue could be critical for SLA (second language acquisition) because most of the second language learners stay at the beginning stage of second language development much longer than do those of native speakers, and word knowledge would play a more critical role in L2 reading.

The relation between L2 reading and working memory was explored by Harrington and Sawyer (1992). In order to test the extent to which differences in L2 reading skill can be reliably related to differences in L2 working memory capacity, three types of working memory measures – digit span, word span, and reading span – were given to 35 Japanese advanced English language learners in both Japanese and English. TOEFL grammar, TOEFL reading, and 350-word cloze tests were used as L2 comprehension measures. The result of the study was that only the correlation between English reading span task (central executive) and TOEFL reading was found to be significant. Both English digit span and English word span (phonological loop) failed to show any significant effect on L2 reading, which is consistent with the findings of L1 reading studies. Concerning working memory in L1 and L2, the correlation between L1 and L2 reading spans (central executive) was significant but only at the $p<.05$ level, whereas the correlations between L1 and L2 digit and word spans (phonological loop) were significant at the $p<.01$ level. An issue of whether L1 and L2 working memory show consistently significant correlations, independent of
relative proficiency in L2 is worth further exploring in order to see whether working memory is not only domain-general like fluid intelligence but also mode-general (over different languages).

The central executive was explored by Osaka et al. (2002) at a finer grain size. Noting the function of inhibiting irrelevant information for better recall in the reading span task (RST) (Daneman & Carpenter, 1980), which belongs to a processing aspect of working memory and thus, the central executive, they created two conditions; focused RST, where the word to be recalled is the focus word in meaning (no inhibitory process involved); and nonfocused RST, where the word to be recalled is any word other than the focus word in the sentence, which consequently involves taxing an inhibitory function of the central executive for attentional control. In the first experiment, they tested the effect of focus word for recall. The recall task of 30 Japanese participants under the two types of conditions (focused RST and nonfocused RST) revealed that the mean span score was significantly higher for the focused RST than for the nonfocused RST, confirming the effect of focus word in meaning for better recall. In the further analysis on the intrusion error (the number of nontarget words belonging to the set of sentences that were incorrectly recalled), they found that in the nonfocused condition, the rate of providing a focus word for recall was significantly higher than that of providing other nontarget words. This attests the stronger power of focus word in meaning for recall than other nontarget words in the sentence.

In order to test individual differences in an ability to inhibit irrelevant information using a focus word as a distracter for recall, Osaka et al. (2002) also compared 23 high WM subjects with 23 low WM subjects using the same task in the first experiment. ANOVA revealed that there was a significant main effect of focus and WM group along with a significant interaction between them. Further analyses showed that recall was higher for the focused RST than for the nonfocused RST for the low WM group, whereas there was no significant difference in recall between the focused RST and the nonfocused RST for the high WM group. The significant difference between the focused and nonfocused RST groups for the low WM group indicates that distracters (focus word in nonfocused RST condition) made a significant confusing effect in the recall task, and those in the low WM group were not able to inhibit distracters successfully due to their low working memory resources. However, this confusing effect of distracters was not found in high working memory group – their high WM resource enabled them to successfully inhibit the distracters. These findings lead us to a conclusion that an ability to inhibit irrelevant information, which belongs to processing, does explain individual differences in recall. Even though this central executive component of working memory was conducted at a sentence level in this study, the findings may be applicable to text comprehension in that text...
comprehension involves building a mental representation of hierarchical information in its importance, and this requires an ability to differentiate less or more relevant information and suppress the former type of information throughout the whole course of reading.

Noting the storage (recall a final word) component and a processing component (comprehending a sentence) of reading span tasks (RST), Alptekin and Ercetin (2010) analyzed the scores of recalling a final word and the scores on grammaticality judgment tasks of each sentence in the reading span tasks both in L1 (Turkish) and L2 (English); 43 Turkish college students whose TOEFL scores were above 550 and who were taking English-mediated courses participated in the study. Interestingly, the scores on storage and the scores on processing were significantly negatively correlated in L1 working memory (-.541); the correlation between the two components in L2 working memory was negative as well but failed to reach a significant level (-.287). Even though the interpretation of this negative relationship needs to be made cautiously because grammaticality judgment tasks may have involved linguistic knowledge, it is highly plausible that the observed negative correlation is indicative of a trade-off between the processing and storage components of working memory" (Alptekin & Ercetin, 2010, p. 213). Concerning the relationships between L1 working memory and L2 working memory, both the correlation between L1 and L2 processing (.529) and that between L1 and L2 storage (.629) were statistically significant. Alptekin and Ercetin concluded that these significant correlations “suggest that the cognitive resources underlying working memory capacity in the L1 are analogous to those in the L2” (p. 213). However, the unexpected finding that unlike L1 working memory, correlation between storage and processing in L2 working memory was not significant (-.278) needs further investigation. How L2 working memory changes as L2 proficiency improves, what feeds into the improvement of L2 working memory, and how the relationship between a storage component and a processing component changes over different levels of L2 proficiency appear to be worth further research.

IV. NEW COMPONENT, EPISODIC BUFFER /LONG-TERM WORKING MEMORY

The newest component, the episodic buffer (Baddeley, 2000) is an addition to its original three component model. Baddeley (2007) explicated that the capacity to remember large chunks of prose that has been observed in many studies needs to be addressed in his model of working memory. In fact, the concept of the episodic buffer was addressed by Erricson and Kintsch (1995), who termed it as ‘long-term working
memory’ (LT-WM). They argued, “as working memory has been considered in a wider range of complex tasks, theorists have found it increasingly difficult, if not impossible, to model the associated cognitive processes with only around four chunks in working memory” (pp. 212-213), the number which traditional short-term memory (STM) had generally found to be possible for memory, and which is mostly consistent with the limited capacity of working memory for many unfamiliar tasks used in laboratory studies. According to Erricson and Kintsch (1995), the model Baddeley and Hitch (1974) proposed did not explain working memory for skilled activities, in which a huge amount of information held in the LTM can be activated for immediate use to meet current or on-line task demands as shown in the studies by Chase and Simon (1973). They found that chess experts could utilize a large number of specific patterns of chess pieces in LTM when given representative stimuli from their domain of expertise as retrieval cues while the expert’s advantage disappeared with chess boards as stimuli that have randomly arranged chess pieces in the memory tasks.

Kintsch (1998) explained that more direct evidence of LT-WM for text comprehension comes from the study by Glanzer et al., (Fischer & Glanzer, 1986; Glanzer, Dorfman, & Kaplan, 1981; Glanzer, Fischer, & Dorfman, 1984). The task they used was a text with an unrelated sentence inserted after each sentence of the text for various lengths of time. Surprisingly, they found no effect of the interruptions whatever on comprehension; there was no difference in accuracy of comprehension questions between the interrupted text and the text without any interruptions. Kintsch (1998) argued that the classical theory of working memory cannot explain these results because reading an unrelated sentence was supposed to wipe out any traces of the prior text from the reader’s STM in the classical model. He instead claimed that the theory of LT-WM readily accounts for the observed results; “The next sentence of a text following an interruption provides the cues in STM that can retrieve the LTM trace of the previous text from LT-WM. The mental structure that the reader has created in the process of comprehending the text itself functions as a retrieval structure” (p. 223). Thus, associative semantic strength among sentences in the text allowed subjects to suppress the effect of interruptions and enabled them to hold the coherent mental representation of the text. Baddeley (2007, p. 12) acknowledged that “performance on such complex tasks as reading comprehension could not be explained within the existing framework [the model of three-component working memory], where memory storage was limited to the loop and the sketchpad, each of which could hold information only briefly, and which had no specified means of interaction”. Then, Baddeley suggested that the episodic buffer which is “assumed to form an interface between the three working memory subsystems and long-term memory” (p. 13) works as a “binding mechanism that allowed perceptual information,
information from the subsystems, and information from long-term memory to be integrated into a limited number of episodes” (p. 13).

Even though no study has explored the role of episodic buffer in reading comprehension yet, it is plausible that the beneficial effect of background knowledge may be better explained by episodic buffer than the three component model. The ability to activate relevant background knowledge from long-term memory and create strong and appropriate associations with incoming new information in texts would have good explaining power for individual differences in both L1 and L2 reading. Despite the absence of a tool that operationalizes LT-WM, studies that explored the impact of background knowledge in relation to working memory can help understand the function LT-WM indirectly.

V. WORKING MEMORY AND THE EFFECT OF BACKGROUND KNOWLEDGE IN L1 AND L2 READING

There is now considerable evidence that background knowledge plays a crucial role in facilitating reading comprehension (e.g., Bransford & Johnson, 1972; Ericsson & Kintsch, 1995; Moravcsik & Kintsch, 1993; Vicentre & Wang, 1998). As aforementioned, the benefit of background knowledge can be clarified with the working memory framework because it is assumed that the availability of background knowledge from the long-term memory can mitigate the cognitive demand for a given reading task. Since the working memory is limited in its capacity, the burden of working memory is reduced for readers with more knowledge relevant to the topic.

Cohen and Wingfield (2006) hypothesized that contextual knowledge would increase reading efficiency by reducing demands on WM capacity, which would be supported by 1) increased reading efficiency among readers given prior contextual knowledge relative to those not given this knowledge and 2) larger differences in reading efficiency between high and low WM span groups among readers without prior knowledge than among readers with prior knowledge. 200 young and older adults in total were divided into either a title or a no-title group, which operationalized contextual knowledge within each age group (young vs. older). The measure for working memory was a loaded sentence span task, in which the participants were asked to respond “true” or “false” to an increasingly larger set of sentence statements and were asked to repeat the list of sentence-final words from that set in a correct order. The reading efficiency was computed by dividing the median cause reading time for each passage by the number of propositions recalled for it. The findings supported their hypotheses; ANOVA (between subjects comparison) revealed a
significant main effect of working memory span, which indicates that the reading efficiency varied as a function of working memory capacity (confirmation of the hypothesis #1), and significant interaction with contextual knowledge (title), which suggests that WM span was more important among participants who did not receive passage titles than among those who did (confirmation of the hypothesis #2). The findings indicate that the no title text created a condition where readers should tax more cognitive resources for comprehension, and this cognitively more demanding condition favored those with high WM who could spare additional cognitive resources to compensate for the lacking information. Thus, the results confirmed the assumption about the compensatory function of working memory and background knowledge for reading comprehension.

Topic familiarity in L2 Reading and working memory was investigated by Lesser (2007). He reported that topic familiarity has been found to have a significant positive effect (either main effect or part of complex interaction) in various L2 reading studies (for example, Barry & Lazarte, 1995; Bugel & Buunk, 1996; Carrell & Wise, 1998; Chen & Donin, 1997; Johnson, 1982; Pulido, 2003, 2007), although such effects have not been observed in a few studies (Hammadou, 1991; Peretz & Shoham, 1990). He analyzed the scores of topic familiarity and WM (the composite z scores of mean reaction times for the correctly judged sentences, the number of correctly judged sentences, and the number of sentence-final words correctly recalled) in relation to comprehension recall as a dependent variable. The 94 participants were beginning Spanish learners of English native speakers in college. The result of ANOVA showed significant main effects for topic familiarity and for working memory; the high WM group recalled a greater percentage of text propositions than the low WM group, and the difference between medium and low also approached significance. The analysis with Pairwise Tukey HSD post hoc comparisons revealed that the higher WM groups (high and medium) that read familiar passages outperformed learners who read unfamiliar topic passages regardless of WM. Within the familiar condition, those with high and medium WM recalled more than those with low WM, whereas there was no significant difference among the WM groups in the unfamiliar condition.

This result is not consistent with what Cohen and Wingfield (2006) found in L1 reading; differences between high and low WM groups were greater within the no title condition, which is equivalent to the unfamiliar condition in Lesser’s (2007) study than in the title condition, equivalent to familiar condition. This conflicting evidence on the role of background knowledge in relation to working memory has been addressed by Hambrick and Engle (2002) and Hambrick and Oswald (2005) in their three hypotheses on possible patterns of interplay between domain knowledge and WM on comprehension. The compensation hypothesis states that “domain knowledge
attenuates the influence of working memory capacity on higher-level cognition, whereas the *rich-get-richer hypothesis* predicts that working memory capacity enhances use of domain knowledge" (Hambrick & Oswald, 2005, p. 377). The third hypothesis, the *independent influence hypothesis* predicts simply that "working memory capacity and domain knowledge make additive contributions to higher-level cognition" (Hambrick & Oswald, 2005, p. 377). The finding in Cohen and Wingfield (2006) supports the *compensation hypothesis* in that the title condition did not favor the higher WM group but the lower WM group, whereas what was observed in Lesser’s (2007) study supports the *rich-get-richer hypothesis* because both the high WM capacity and the topic familiarity benefited the higher WM group. However, what Hambrick and Oswald (2005) found in their study (a relationship between WM and domain knowledge such as a baseball task and a spaceship task) was consistent with the *independent influence hypothesis*; “even at high levels of baseball knowledge, this knowledge use did not alter the relationship between working memory capacity and task performance” (Hambrick & Oswald, 2005, p. 377).

Thus, it is concluded that each of the hypotheses has empirical evidence to support.

My own interpretation of these results is that the relationship between working memory and domain knowledge may be task-dependent. The crucial difference between two conditions in Cohen and Wingfield’s (2006) study (L1 reading) and Lesser’s (2007) study (L2 reading) appears to be in the cognitive demands imposed on each type of task. Since L2 reading entails dual-language processing at all levels of comprehension, it goes without saying that it imposes higher cognitive load than L1 reading does. In such a demanding condition, any kind of additional resources is likely to make a difference; thus, a *rich-get-richer hypothesis* is validated. L2 readers with higher WM in Lesser’s (2007) study were in fact able to make use of all the usable resources (higher WM and familiar topic). However, the unfamiliar L2 reading condition might have caused a floor effect in the unfamiliar topic condition due to the extremely high cognitive demand (unfamiliar topic and dual-language processing), validated by the finding of no differences between the high WM and low WM groups. Unlike L2 reading condition, the title condition in L1 reading might have resulted in a ceiling effect; thus, no difference observed between the high WM and the low WM groups in Cohen and Wingfield’s (2006) study. Even though the seemingly conflicting results found in Cohen and Wingfields’s (2006) and Lesser’s (2007) studies may be attributed to differential cognitive demands required to process each task, more qualitative studies need to be done to explain specific cognitive processes responsible for the observed differences. The comparative analysis of conditions used in Hambrick and Oswald (2005) also needs to be conducted at a finer grain size in relation to the tasks in Cohen and Wingfield (2006) and Lesser (2007).
VI. CONCLUSION

Kintsch (1998) argued, “Explanations of complex cognitive processes have too many degrees of freedom. That is, there are too many ways to explain a local phenomenon, so that it is not possible to tell which one is right or best” (p. 1). He further suggested using a simple theory that roughly encompasses various phenomena. Although it is far from being complete, working memory may serve the function of this single theory for L1 and L2 reading that Kintsch (1998) advocated. Working memory is a domain-general construct that has shown consistent significant contribution as an independent variable to both L1 and L2 reading. A multi-component model of working memory along with a newly introduced construct, episodic buffer or long-term working memory helps clarify differential roles of working memory in interacting with other complex cognitive processes.

The importance of phonological loop in the beginning stage of L1 reading (a better phonological storage capacity leads to better vocabulary acquisition) needs to be investigated in relation to L2 reading. Unlike L1 readers, L2 readers in an EFL setting do not get exposed to L2 sound to a great degree and should develop their L2 skills over a much longer period of time under the influence of L1. Specific instructional methods such as reciting or speech shadowing need to be studied in order to find out whether promoting sound familiarity by oral practices would indeed mitigate a cognitive demand on working memory (phonological loop), which would in turn enhance the acquisition of L2 vocabulary and the efficiency of L2 reading. One recent study (Walter, 2008) addressed the issue indirectly; the study adopted a task of recalling a word sequence to measure phonological loop, but both the presentation of the word list and the recall of the sequence were conducted in a written form without any sound-involvement. It was shown that L2 (English) readers of good L2 decoding and good L1 (French) comprehension abilities were differentiated in their L2 summary completion tasks according to their recall abilities of L2 word sequences. Based on the findings, Walter (2008) maintained that “it may be the case that all the PoorCs [those with good L1 comprehension and good L2 decoding abilities but poor L2 reading comprehension] need is more exposure to the target language” (p. 470). However, since the kinds of exposure to the target language may vary, specific types of exposure that could work best in an EFL (English as a foreign language) setting need to be classified and tested. A cooperative action research among language teachers may be launched to find an answer to this question.

The findings of the various studies consistently showed that the central executive, which is an attentional control system, is one of the most important players in explaining L1 and L2 reading comprehension. How this attentional control system
interacts with background knowledge (Cohen & Wingfield, 2006; Lesser, 2007) has important pedagogical implications because three different phenomena (Compensation Hypothesis, Rich-get-richer Hypothesis, and Independent Influence Hypothesis) can be observed depending on learners’ characteristics and task characteristics. Coming up with systematic methods (identifying instructional components that impose differential degrees of cognitive load on readers) can help teachers manipulate instructional activities to create an optimal condition for learning for a particular group of students.

How background knowledge and L2 proficiency contribute to L2 reading comprehension may be explored under the limited capacity of working memory. As shown in the studies (Hambrick & Engle, 2002; Hambrick & Oswald, 2005; Cohen & Wingfields, 2006; Lesser, 2007), rich background knowledge facilitates comprehension in L1 and L2 reading sometimes of a high working memory group and at times of a low working memory group. Whether boosting topic familiarity enhances L2 acquisition needs to be explored as well. With the increased use of content-based instruction for L2 development in universities and colleges, these questions appear to be more than worth a further exploration.

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