



Available online at:

<http://dergipark.ulakbim.gov.tr/eltri/>

International Association of Research

in Foreign Language Education and Applied Linguistics

ELT Research Journal

2015, 4(2), 101-110

ISSN: 2146-9814

Working memory and L2 reading: theoretical and methodological issues

Gülcan Erçetin¹

Boğaziçi University, Istanbul-Turkey

Abstract

This article reviews research on working memory (WM) and its role in second language (L2) reading. After a brief theoretical account of WM, the article focuses on methods of measuring WM and issues surrounding its measurement. Next, the paper provides a review of studies on the relationship between L1 and L2 WM, their relationships with L2 reading, and the interaction between WM capacity and domain knowledge in terms of their effects on L2 reading comprehension. Conclusions regarding the role of WM in relation to literal and inferential reading are drawn and suggestions for further research are offered.

Keywords: Working memory; L2 reading; literal comprehension; inferential comprehension

¹ Associate Professor, Boğaziçi University, Foreign Language Education Department.
Email: gulcaner@boun.edu.tr

Introduction

The role of working memory (WM) in L2 learning has been investigated with regards to sentence processing (Felser & Roberts, 2007; Juffs, 2004, 2005), vocabulary development (Martin & Ellis, 2012), learning grammar (Williams & Lovatt, 2003), writing (Abu-Rabia, 2003; Adams & Guillot, 2008), and speaking (Fortkamp, 1999; O'Brian, Segalowitz, Collentine, & Freed, 2006). This paper will limit its scope with the relationship between WM and L2 reading.

One of the most widely acknowledged models of WM has been proposed by Baddeley (2000, 2003). Although alternative models exist (e.g., Cowan, 2005; Ericsson & Kintsch, 1995), Baddeley's model constitutes the framework for most of the research conducted in the field. The model consists of three domain-specific short-term storage subcomponents, namely the phonological loop, the visuospatial sketchpad, and the episodic buffer as well as a domain general attentional mechanism controlling these sub-systems called the central executive. The phonological loop stores speech-based verbal information. It is designed for sequential learning and plays a crucial role in language learning, particularly phonological processing, speech development and vocabulary learning. The visuospatial sketchpad stores visual and spatial information and is suited for holistic learning. Although the sketchpad is not essentially associated with language learning, Baddeley (2003) suggests:

the system will be involved in everyday reading tasks, where it may be involved in maintaining a representation of the page and its layout that will remain stable and facilitate tasks such as moving the eyes accurately from the end of one line to the beginning of the next. (p. 200)

The episodic buffer is a sub-system that simultaneously stores multiple sources of information. It can combine information from long-term memory (LTM) with the information from short-term storage systems. Finally, the central executive is a domain general limited capacity attentional system that controls the short-term storage systems; its functions include focusing, dividing, and switching attention (Baddeley, 2002). Hence, the buffer is involved whenever simultaneous storage and processing of information is required (Dehn, 2008). It is generally assumed that individual differences in WM are determined by central executive processes. Research has shown that both the central executive and the phonological loop have central roles in L1 (e.g., Baddeley, 2003; Bowey, 2001; Daneman & Hannon, 2007; Engle, 2002) and L2 language processing (e.g., O'Brien et al., 2006; Service, 1992; also see Juffs & Harrington, 2011 as well as Linck, Osthus, Koeth, & Bunting, 2014 for meta analyses).

Baddeley's structural model of WM suggests that WM and short-term memory (STM) are separate constructs with different functions. While STM passively holds information and has no management functions, WM actively processes information and has executive functions such as focusing attention on relevant information while inhibiting irrelevant information (Dehn, 2008). Moreover, STM is domain specific, storing verbal or visual/spatial information whereas WM is domain general. Finally, STM activates information stored in LTM but it can operate independently from LTM, whereas WM is highly interactive with LTM since its operations depend on LTM representations. For instance, when multiple meanings of a word are activated in LTM, WM inhibits the irrelevant meanings and brings the

relevant meaning into conscious attention. Considering the close interaction between WM and LTM, Ericsson and Kintsch (1995) have made a distinction between short-term WM (ST-WM) and long-term WM (LT-WM). The former refers to short-term storage of information while the latter refers to the skilled use of storage in LTM (Ericsson & Kintsch, 1995, p. 211).

Measurement of WM capacity

Span tasks used in reading research can be classified as simple and complex tasks. Since the former requires only passive retention of information, it is considered to measure phonological short-term memory. Examples of simple span tasks include but not limited to forward digit span, letter span, and word span. Specifically, these tasks require the recall of a list of unrelated digits, letters, words, and so on. Complex span measures, on the other hand, require effortful processing of information while storing a list of items for a short interval. They measure verbal and executive working memory.

Complex span tasks involve a primary task, which corresponds to recall of items and a secondary task, which corresponds to processing of given stimulus. The most commonly used complex span task in reading research is the reading span task (RST). The original RST (Daneman & Carpenter, 1980) required the test taker to read given sentences aloud (secondary task) and recall the sentence-final words (primary task). Later versions, most of which are computerized, have incorporated a sentence verification task as the secondary task. In other words, the test taker is supposed to judge grammatical accuracy or semantic plausibility of the sentences so that processing is ensured. The sentences are generally presented in sets of two to five. Thus, the storage load is based on the number of sentences in a given set. High correlations have been observed between RST and reading comprehension in the L1 (see the meta-analysis by Daneman & Merikle, 1996).

A variation on the RST is the listening span task (LST), which requires listening to sentences and recalling sentence final words. A complex span task that involves a nonlinguistic processing component is the operation span task (OST) where the secondary task requires judging the accuracy of given operations while recalling words associated with each operation. Backward digit span is also a nonlinguistic complex span task in which given digits are repeated backwards.

Reliability & Validity Issues in Complex Span Tasks

Several issues can be raised regarding the validity and reliability of complex span tasks in general and in L2 research in particular. First, whether the nature of the secondary task makes a difference in the assessment of WM capacity is of major concern. That is, whether tasks, which use sentence verification vs. arithmetic operations vs. counting backwards are comparable and lead to consistent results in the assessment of working memory. This issue can be examined in relation to two hypotheses regarding the nature of WM capacity. The *specific processing hypothesis* (Daneman & Carpenter, 1980; Waters & Caplan, 1996) posits that the secondary task should be a verbal task to accurately measure verbal WM capacity. It is thought that expertise at the processing task frees additional WM capacity for the storage component of the task (Dehn, 2008). Thus, according to this view, WM span should be larger in more proficient languages and shorter in less familiar languages. On the other hand, *the*

general processing view (Towse, Hitch, & Hutton, 1998) suggests that WM is domain general. The resources underlying WM's storage and processing functions are similar irrespective of the nature of the task or the type of domain. Therefore, any task that requires focused attention in the presence of distraction (Dehn, 2008) could be appropriate for WM assessment.

The RST that has been shown to have substantial correlations with L1 reading ($r = .50 - .90$) can be taken under scrutiny in relation to these hypotheses. If the task specific view is correct, then the correlations between the RST scores and reading comprehension can be attributed to the linguistic skills tapped by the measures. For instance, Waters and Caplan (1996) found that most of the variance shared by the RST and reading comprehension was due to the processing component, with significant but small contribution of the storage component. Similarly Koda (2005) argues that it is possible for tasks used to measure WM capacity to also measure similar or even identical abilities in reading. Finally, Kintsch (1998) maintains that the RST measures the efficiency with which readers can comprehend sentences and hence store them in LTM. Therefore, it is the differences in language skills, not in STM capacity that distinguish good and poor readers. Based on these arguments, one could claim that the relationship between the RST scores and reading comprehension scores cannot be attributed to differences in WM capacity since language seems to predict language.

Contrary evidence to this view comes from the proponents of the task general view. For instance, Turner and Engle (1989) have demonstrated that both RST and OST scores were significantly correlated with reading measures. Hence, Conway et al. (2005) argue that the underlying structure is the same for counting span, reading span, and operation span tasks. Based on a comprehensive meta-analysis of studies conducted in the L1, Daneman and Merikle (1996) concluded: "The predictive power of the WM does not depend on a process component that taps language comprehension processes; as long as the processes involve the manipulation of symbolic information (i.e., words or digits)" (p. 430).

Another issue that concerns the reliability and validity of complex span tasks is the type of score used as indicative of WM capacity. While the majority of the studies employed the storage scores, there are studies that employed composite scores. These differences can be based on two opposing views regarding the relationship between processing and storage tasks. The *shared resources hypothesis* posits that processing and storage demands compete for a limited, common pool of resources. Therefore, they are in a trade-off relationship, which can best be represented with a composite score based on the average of standardized processing and storage scores (Waters & Caplan, 1996). On the other hand, the *separate resources hypothesis* puts forward that storage and processing demands are independent because they require different types of resources. Thus, the storage scores can be used to represent WM capacity (Conway et al., 2005).

An issue that is of major concern in L2 studies is whether the language of the task (L1 vs. L2) would affect accurate assessment of WM capacity. Those who oppose to the use of RST in the L2 base their argument on the potential confounding effects of L2 language proficiency. Thus, they suggest that a nonlinguistic span task should be used in L2 studies. In addition, comparability of measures across languages is of major concern when L1 and L2

span is compared. Specifically, sentence-final words in some languages will be nouns (e.g., English) but in others it will be verbs (e.g., Turkish). When scores from L1 and L2 RSTs are compared, would recall of nouns and verbs be comparable? To avoid this problem, in some studies (e.g., Juffs, 2004, 2005), RST storage task required the recall of sentence internal word so that the target word recalled would be a noun. However, this solution poses another potential comparability problem, i.e., recall of sentence-final vs. sentence-internal words. Finally, word length needs to be considered as it has been shown that it is easier to recall a sequence of short words than long words (Baddeley, 2000).

Issues in Investigating the Role of WM in L2 Reading

Majority of the studies investigating the role of WM in L2 reading treated reading as a global construct, disregarding its multi-level representational nature in terms of forming of the textbase and the situation model (Kintsch, 1998). The textbase consists of text-driven propositions which are primarily based on the meaning and rhetorical structure of the text, with minimal links to LTM. The reader mainly uses syntactic and semantic knowledge to arrive at textual meaning. Local level inferences may be needed when arguments do not overlap. Kintsch (1998) suggests that ST-WM may play a major role to form a coherent textbase for readers with low topical knowledge. The situation model on the other hand, involves knowledge-driven propositions combined with the textbase. LTM structures are used to organize and elaborate the textual material. LT-WM plays a major role in forming a situation model for high-knowledge readers. Few studies (Alptekin & Erçetin, 2010, 2011; Rai, Loschky, Harris, Peck, & Cook, 2001) examined WM's relationship to literal comprehension corresponding to the textbase versus inferential comprehension corresponding to the situation model.

Research on the role of WM in L2 reading has mainly focused on the relationship between L1 and L2 WM, their relationships with L2 reading, and the interaction between WM capacity and domain knowledge in terms of their effects on L2 reading comprehension.

Regarding the relationship between L1 and L2 span, early studies by Osaka and Osaka (1992) as well as Osaka, Osaka, and Gröner (1993) have demonstrated strong correlations between L1 and L2 reading span ($r > .80$), suggesting that WM processes are independent of language. Other studies based on RST or LST scores, despite not finding such strong relationships, generally point to substantial relationships across different languages (e.g., Alptekin & Erçetin, 2010, Alptekin & Erçetin, Özemir, 2014; Juffs, 2005; Miyake & Friedman, 1998; Service, Simola, Metsaenheimo, & Maury, 2002), suggesting shared resources between L1 and L2 span. A close examination of the participants' performance on span tasks revealed that available WM resources diminish as proficiency level decreases. In other words, storage capacity and processing accuracy are better in the L1 compared to L2, which is also better compared to L3 ($L1 > L2 > L3$) (Van den Noort, Bosch, & Hugdahl, 2006). Nevertheless, it can be argued that the differences between L1 and L2 spans diminish, as proficiency level gets higher. Supporting evidence for this comes from Service et al. (2002) who found that the participants less fluent in L2 had larger spans in their L1, whereas this difference was not significant for the more advanced speakers. Similarly, Alptekin and Erçetin (2010) have shown that the storage capacity did not differ between L1 and L2 for

advanced learners of English, yet the processing accuracy was still higher in L1 than L2 (L1 processing > L2 processing > L1 storage = L2 storage).

As for the relationship between WM capacity and L2 reading, research studies have shown that L2 reading span scores have stronger correlations with L2 reading comprehension compared to L1 reading span. The amount of variance shared by L2 span and L2 reading typically ranges between 20 - 38 percent (e.g., Alptekin & Erçetin, 2010; Harrington & Sawyer, 1992; Service et al. 2002; Walter, 2004). On the other hand, studies that examined the relationship between WM and L2 reading with measures different from RST found that they either did not predict reading or had very low correlations (e.g., Payne, Kalibatseva, & Jungers, 2009; Leiser, 2007). As such, given the substantial correlations between L1 and L2 span but the direct relationship between L2 span and reading, it can be argued that L2 WM capacity is directly related to L2 comprehension, with L1 WM capacity being chiefly a mediator (Miyake & Friedman, 1998). As Geva and Ryan (1993) put it: “Seemingly parallel L1 and L2 memory measures are not completely interchangeable” (p. 30).

A question of considerable interest is the relationship between WM capacity and L2 reading when domain knowledge or topic familiarity is taken into account. Three models have been proposed regarding the combined effects of WM capacity and domain knowledge on cognitive performance in general (Hambrick & Engle, 2002). The *compensation model* posits that domain knowledge attenuates the effects of WM capacity. Thus, there should be no difference between high- and low-WM capacity individuals when domain knowledge is sufficient. The *rich-get-richer model* postulates that WM capacity strengthens the effect of domain knowledge as people with high levels of WM capacity benefit from preexisting domain knowledge to a greater extent than people with lower levels of WM capacity. The *independent influences model* suggests that WM capacity and domain knowledge have additive and independent effects on cognitive performance. Few studies have tested these hypotheses in relation to L2 reading. Leiser (2007) found a marginally significant interaction between reading span and topic familiarity in terms of text recall of beginning level learners of Spanish. Whereas the findings of Payne et al. (2009) point to significant and independent contributions of WM and domain knowledge operationalized as the level of proficiency in the L2. Alptekin and Erçetin (2011) have also found significant and independent contributions of L2 reading span and content familiarity to inferential comprehension, but not to literal understanding.

Conclusions

Methodological inconsistencies in the existing studies hinder making generalizations about theoretical issues such as the relationship between L1 and L2 WM, the role of WM in L2 reading, and the interaction between WM and domain knowledge. Nevertheless, certain pedagogical suggestions can be made based on the available findings.

Given the high intrinsic load associated with reading in a foreign language, WM load should be lowered as much as possible so that learners have available resources for higher level reading operations such as inferencing. At lower proficiency levels, learners will struggle with forming a coherent textbase. Therefore, textbase formation will put a high load on WM or in Kintsch's term ST-WM. At this level, teachers should choose texts, which have

an explicit structure to aid forming of the textbase. Topic familiarity is essential to aid forming of the situation model. At higher proficiency levels, literal comprehension or forming the textbase does not involve high WM load since literal comprehension chiefly depends on language ability. As proficiency increases, lower level processes become more automatic and WM has a more influential role in inferential comprehension. Learners at this level can deal with texts with less explicit structure. However, topic familiarity is still essential to aid forming of the situation model.

Suggestions for further research

A number of suggestions for future research are warranted based on the review of literature presented in this paper. First, it should be noted that most of the studies were conducted with relatively proficient L2 learners. Learners with lower proficiency levels should also be included in future research, especially in investigations of the interaction between WM capacity and domain knowledge. Second, a comprehensive study on different measures of WM both in L1 and L2 investigating their reliability and validity for L2 populations is essential. Third, considering the domain-specific vs. domain-general view of WM, the issue of what type of measure should be used as indicative of WM capacity in exploring WM's relationship with skills such as listening comprehension, written and oral production needs further investigation. Fourth, the degree of relationship between WM capacity and the type of inferences drawn (e.g., elaborative versus bridging) should be further studied with L2 populations. Finally, considering the correlational nature of existing research, intervention studies that focus on training of WM capacity may add to our understanding of the role of WM capacity in L2 reading.

References

- Abu-Rabia, S. (2001). Testing the interdependence hypothesis among native adult bilingual Russian-English students. *Journal of Psycholinguistic Research*, 30, 437–455.
- Adams, A. M., & Guillot, K. (2008). Working memory and writing in bilingual students. *International Journal of Applied Linguistics*, 156, 13–28.
- Alptekin, C., Erçetin, G., & Özemir, O (2014). Effects of variations in reading-span task design on the relationship between working memory capacity and second language reading. *The Modern Language Journal*, 98, 536–552.
- Alptekin, C., & Erçetin, G. (2010). The role of L1 and L2 working memory in literal and inferential comprehension in L2 reading. *Journal of Research in Reading*, 33, 206–219.
- Alptekin, C., & Erçetin, G. (2011). Effects of working memory capacity and content familiarity on literal and inferential comprehension in L2 reading. *TESOL Quarterly*, 45, 235–266.
- Baddeley, A. D. (2002). Is working memory still working? *European Psychologist*, 7, 85–97.

- Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Science*, 4, 417-423.
- Baddeley, A. D. (2003). Working memory and language: An overview. *Journal of Communication Disorders*, 36, 189-208.
- Bowey, J. A. (2001). Nonword repetition and young children's receptive vocabulary: A longitudinal study. *Applied Psycholinguistics*, 22, 441-469.
- Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, 12, 769-786.
- Cowan, N. (2005). *Working memory capacity*. Hove, UK: Psychology Press.
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, 19, 450-466.
- Daneman, M., & Hannon, B. (2007). What do working memory span tasks like reading span really measure? In N. Osaka, R. H. Logie & M. D'Esposito (Eds.), *The cognitive neuroscience of working memory* (pp. 21-42). New York, NY: Oxford University Press.
- Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review*, 3, 422-433.
- Dehn, M. (2008). *Working memory and academic learning: Assessment and intervention*. New Jersey, NJ: Wiley.
- Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, 11, 19-23.
- Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, 102, 211-245.
- Felser, C., & Roberts, L. (2007). Processing *wh* dependencies in a second language: A crossmodal priming study. *Second Language Research*, 23, 9-36.
- Fortkamp, M. B. M. (1999). Working memory capacity and aspects of L2 speech production. *Communication and Cognition*, 32, 259-296.
- Geva, E., & Ryan, E. B. (1993). Linguistic and cognitive correlates of academic skills in first and second languages. *Language Learning*, 43, 5-42.
- Hambrick, D. Z., & Engle, R. W. (2002). Effects of domain knowledge, working memory capacity, and age on cognitive performance: An investigation of the knowledge-is-power hypothesis. *Cognitive Psychology*, 44, 339-387.
- Harrington, M., & Sawyer, M. (1992). L2 working memory capacity and L2 reading skill. *Studies in Second Language Acquisition*, 14, 25-38.
- Juffs, A. (2004). Representation, processing and working memory in a second language. *Transactions of the Philological Society*, 102, 199-225.

- Juffs, A. (2005). The influence of first language on the processing of wh movement in English as a second language. *Second Language Research*, 21, 121–151.
- Juffs, A., & Harrington, M. (2011). Aspects of working memory in L2 learning. *Language Teaching*, 44, 137–166.
- Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. New York, NY: Cambridge University Press.
- Koda, K. (2005). *Insights into second language reading: A cross-linguistic approach*. New York, NY: Cambridge University Press.
- Leeser, M. J. (2007). Learner-based factors in L2 reading comprehension and processing grammatical form: Topic familiarity and working memory. *Language Learning*, 57, 229–270.
- Linck, J. A., Osthus, P., Koeth J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review*, 21, 861–883.
- Martin, K. I., & Ellis, N. C. (2012). The roles of phonological short-term memory and working memory in L2 grammar and vocabulary learning. *Studies in Second Language Acquisition*, 34, 379–413.
- Miyake, A., & Friedman, N. P. (1998). Individual differences in second language proficiency: Working memory as language aptitude. In A. F. Healy & L. E. Bourne (Eds.), *Foreign language learning: Psycholinguistic studies on training and retention* (pp. 339–364). Mahwah, NJ: Erlbaum.
- O'Brien, I., Segalowitz, N., Collentine, J., & Freed, B. (2006). Phonological memory and lexical, narrative, and grammatical skills in second language oral production by adult learners. *Applied Psycholinguistics*, 27, 377–402.
- Osaka, M., & Osaka, N. (1992). Language-independent working memory as measured by Japanese and English reading span tests. *Bulletin of the Psychonomic Society*, 30(4), 287-289.
- Osaka, M., Osaka, N., & Gröner, R. (1993). Language-independent working memory: Evidence from German and French reading span tests. *Bulletin of the Psychonomic Society*, 31(2), 117-118.
- Payne, T. W., Kalibatseva, Z., & Jungers, M. K. (2009). Does domain experience compensate for working memory capacity in second language reading comprehension? *Learning and Individual Differences*, 19, 119–123.
- Rai, M. K., Loschky, L. C., Harris, R. J., Peck, N. R., & Cook, L. G. (2011). Effects of stress and working memory capacity on foreign language readers' inferential processing during comprehension. *Language Learning*, 61, 187–218.
- Service, E. (1992). Phonology, working memory, and foreign-language learning. *Quarterly Journal of Experimental Psychology*, 45A, 21-50.

- Service, E., Simola, M., Metsaenheimo, O., & Maury, S. (2002). Bilingual working memory span is affected by language skill. *European Journal of Cognitive Psychology, 14*, 383–407.
- Towse, J. N., Hitch, G. J., & Hutton, U. (1998). A re-evaluation of working memory capacity in children. *Journal of Memory and Language, 39*, 195–217.
- Turner, M. L., & Engle, R. W. (1989). Is working memory task dependent? *Journal of Memory and Language, 28*, 127-154.
- Van den Noort, M., Bosch, P., & Hugdahl, K. (2006). Foreign language proficiency and working memory capacity. *European Psychologist, 11*, 289–296.
- Walter, C. (2004). Transfer of reading comprehension skills to L2 is linked to mental representations of text and to L2 working memory. *Applied Linguistics, 25*, 315–339.
- Waters, G. S., & Caplan, D. (1996). The measurement of verbal working memory capacity and its relation to reading comprehension. *The Quarterly Journal of Experimental Psychology, 49A*, 51–79.
- Williams, J. N., & Lovatt, P. (2003). Phonological memory and rule learning. *Language Learning, 53*, 67-121.