

Theoretical Development and Practical Application of Working Memory Capacity in the Field of Second Language Acquisition

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Abstract: *As an important concept in cognitive psychology, working memory has been introduced into the field of second language acquisition in recent years. This paper reviews the theoretical development of working memory and explores the working memory model containing the phonological loop, visuospatial sketchpad, central executive system, and episodic buffer in second language acquisition. By analyzing lots of empirical research literature, this study reveals that working memory can influence L2 learners' acquisition of listening, reading, writing, and interpreting skills. However, some empirical studies also find that working memory may not have significant effects. And the different results may due to differences in measurement methods, L2 learners' individual differences, and variable task complexity. This review synthesizes the current theoretical development and practical applications of working memory in second language acquisition, providing theoretical references for future research and offering recommendations for pedagogical practice.*

Keywords: Psycholinguistics; Working memory; Second language acquisition.

1. Introduction

Working memory, a limited-capacity memory system, can temporarily store and process information (Baddeley & Hitch, 1974). The working memory model initially proposed by Baddeley et al. (1974) consists of the phonological loop, the central executive, and the visuospatial sketchpad. The phonological loop includes two components: phonological storage and articulatory control, and the visuospatial sketchpad is the component responsible for processing visual and spatial information, while the central executive is tasked with coordinating the various components and linking them to long-term memory (Wu & Jin, 2005).

As an important concept in cognitive psychology, working memory has been introduced into second language acquisition research in recent years. Numerous studies have proven that working memory not only affects second language learners' comprehension of content but also influences their second language production. It is widely applied in research on the mastery of second language skills such as listening, speaking, reading, and writing. For example, an empirical study by Harrington and Sawyer (1992) found a positive correlation between the working memory capacity of Japanese second language learners and their second language reading proficiency.

In order to clarify the theoretical development of working memory in second language acquisition and explore its application in language learning processes, this study will first review classic models of working memory and discuss their roles in second language acquisition. Second, the relevant studies will be reviewed to explore the impact of working memory on the acquisition of specific language skills. Finally, the study will discuss how to apply appropriate teaching strategies to accommodate second language learners with different working memory levels, hoping to provide reference for future teaching practices and to help learners with their language learning.

2. Theoretical Development of Working Memory in Second Language Acquisition

In the study of psychology, there are two basic categories of human memory patterns: short-term memory and long-term memory. Because of the difficulty in explaining many complex cognitive activities of the human brain through short-term and long-term memory, the working memory theory was proposed (Cao, 2015). Working memory was initially come up by researchers such as Miller et al. (1960). It was not until 1974 that Baddeley and Hitch further developed the working memory theory and first put forward the three-component model of working memory. This model includes the phonological loop, the central executive system, and the visuospatial sketchpad.

The phonological loop is responsible for storing and controlling verbal information. For second language learners, the process of reading comprehension involves continuously decoding lexical symbols and converting them into meaningful information, and the phonological loop provides a foundation for this stage. Therefore, many researchers have focused on the correlation between the phonological loop and reading comprehension. Studies have testified that the phonological loop is not important for understanding simple sentences but is crucial for understanding longer and semantically complex sentences (Zhang Fayong, 2010). Xu Fang's (2017) meta-analysis indicated that there are relatively more experiments studying the processing of ambiguous sentences and syntactic sentence comprehension from the perspective of verbal working memory, i.e., the phonological loop.

Researchers reckoned that the phonological loop exerts its influence on reading comprehension more when reading complex sentence structures, while the central executive plays a greater role in the processing of linguistic meaning (Wang, 2007). As the core of the entire working memory model, the central executive system is responsible for coordinating resources to achieve information storage and processing (Li, 2007). Studies indicate that the role of the central executive system in language comprehension is primarily manifested in two aspects: one is the maintenance and activation of information over a period of time, and the other is the inhibition of irrelevant information (Zhang & Shen, 2002). Second language learners, whether in understanding listening or reading information, or in translation activities between two languages, need to get effective information and inhibit irrelevant content that impedes comprehension. Therefore, the functions of the central executive system can also be associated with second language acquisition. Zhang's (2010) research found that during simultaneous interpretation, the central executive system must inhibit one's own verbal expression from interfering with one's own verbal listening comprehension, and reasonably and effectively allocate attention to two concurrent cognitive tasks of understanding and expression.

The visuospatial sketchpad is responsible for processing visual information. Depending on its definition, the visuospatial sketchpad holds different significance in information comprehension. If "comprehension" is defined as the ability to decide the truthfulness of a sentence, the visuospatial sketchpad plays an important role in the comprehension process because it helps convert information into visual imagery. However, if "comprehension" is defined as the ability to interpret the meaning of language, the role of visuospatial sketchpad is not that prominent (Glass et al., 1985). The forms of

second language learning have continuously enriched with the development of technology. As multimodal resources, artificial intelligence, and other tools are increasingly applied in second language teaching, learners' visual perception is playing an increasingly significant role in language acquisition. In a multimodal context, second language learners can not only reinforce their memory through visual resources such as pictures and videos but also aid comprehension with body language. In Zhang Fayong's (2010) study, interpreters' observation of the speaker's body language, including gestures, posture, and expressions, as well as the presentation materials containing pictures and videos or on-site images and physical objects, were all crucial for interpreters to understand the speaker's expressions.

Later, Baddeley (2000) added a "episodic buffer" component to his three-component model of working memory. As a limited-capacity temporary storage system, the episodic buffer is controlled by the central executive and can temporarily store memories from different sources. It integrates information such as phonological, visual, and semantic data, providing contextual cues to supplement specific learning content and help memory. Additionally, it connects with long-term memory, assisting learners to transfer learned material from working memory into long-term memory. Furthermore, the episodic buffer can activate knowledge stored in long-term memory under specific contexts, enabling second language learners to retrieve the knowledge.

3. The Applications of Working Memory Theory in Second Language Acquisition

3.1 Working Memory and Listening Comprehension

Existing research indicates a relationship between working memory and first language listening comprehension (Rahimi, 2012). Similarly, Londe's (2008) study demonstrated the relationship between working memory and second language listening comprehension, finding that working memory serves as a latent variable for second language listening in structural equation modeling. When constructing second language listening comprehension, various sub-components of the working memory model play distinct roles. First, the capacity of the phonological loop relates to second language learners' ability to capture information. Second, if learners engage in audio-visual activities, the visuospatial sketchpad can help integrate visual information. Third, the episodic buffer can combine heard information with background knowledge to strengthen understanding. Finally, the central executive is responsible for allocating overall resources, which means that the allocation of attention to listening and note-taking both require the central executive to complete.

Previous studies have analyzed that higher working memory capacity is associated with higher second language listening proficiency (Gu & Wang, 2007; Fay & Buchweitz, 2014; Liu & Yan, 2017). However, there are also studies finding no correlation between working memory and second language listening comprehension (Taguchi, 2008; Zhang & Chen, 2014). These divergent research outcomes may be attributed to various factors, such as differences in how working memory was measured across studies. For example, Liu and Yan (2017) measured participants' working memory using judgments of sentence plausibility and tail-word recall, whereas Zhang and Chen (2014) employed operational working memory span tasks and auditory verbal working memory span tasks. Therefore, standardized measurement methods are crucial for investigating the relationship between working memory and listening comprehension. In addition, individual differences among participants may also contribute to variations in the results, and future research could focus on the impact of working memory on second language learners of different proficiency levels.

3.2 Working Memory and Reading Comprehension

In recent years, researchers have found a significant correlation between working memory and second language learners' reading comprehension (Linck et al., 2014). The phonological loop can activate lexical phonological information when learners engage in silent reading, which is important for understanding alphabetic languages. In the meantime, the visuospatial sketchpad establishes associations between visual form and meaning, playing a role in understanding logographic languages. The central executive system is also responsible for resource allocation. More resources are typically required from the central executive when understanding syntactically complex sentences such as garden-path sentences.

Currently, many studies have found a positive correlation between working memory and second language reading comprehension (Zhang Xiaodong, 2014; Kong Haoxuan, 2024). Some researchers also investigated the impact of different components of working memory on second language reading comprehension, finding that the processing component has a more significant effect (Miao Lixia, 2022; Wang Yuemin & Cui Gang, 2024). Based on the distinction of working memory components, studies have categorized different dimensions of second language reading comprehension. The results indicated that working memory capacity, along with its information processing and storage abilities, significantly predict second language reading accuracy but not second language reading processing efficiency (Ni Jincheng, 2017). Most of these studies measured participants' working memory using reading span tests. Some researchers have further incorporated eye movement metrics to examine how working memory capacity influences second language learners' construction of the macro-structure of English reading (Wang Yuemin & Cui Gang, 2024). However, there are also different results regarding the impact of working memory on second language reading comprehension. For example, Juffs' (2004) study found that working memory has no effect on second language reading efficiency or reading time. Based on the different findings, future research can optimize experimental design by improving measurement methods, refining reading comprehension dimensions, and introducing moderating variables.

3.3 Working Memory and Second Language Writing

According to Kellogg (1996), working memory can influence writing quality, and the capacity of working memory can also affect the accuracy of written language. In the research of second language acquisition, working memory not only influences learners' understanding of input information (such as listening and reading information) but is also associated with output ability. First, during the planning stage of second language writing, the central executive system needs to coordinate content production based on the writing task. Second, during the writing process, learners use the phonological loop and visuospatial sketchpad to assist with vocabulary spelling and text composition. Finally, in the revision stage, working memory still plays a role in supporting learners to check for errors in spelling, syntax, and whether the writing deviates from the tasks.

Currently, the second language researchers have not reached a consensus on the relationship between working memory and L2 writing. From the perspective of second language writing performance, Mavrou's (2020) study indicates that working memory can positively predict learners' writing performance. However, some researchers argue that there is no significant association between working memory and second language writing performance (Li, 2023). Nevertheless, many studies have divided second language writing performance into different dimensions, and proved that working memory can influence the accuracy and syntactic complexity of second language writing (Yi & Ni, 2015). To further clarify the specific role of working memory in writing production, this study analyzes the impact of working memory on different dimensions of second language writing, hoping to enable the development of better writing teaching plans for learners.

3.4 Working Memory and Interpretation

As a relatively advanced professional skill in second language learning and application, interpretation is deeply associated with working memory. Generally speaking, interpreting activities are divided into simultaneous interpreting and consecutive interpreting. In simultaneous interpreting, the phonological loop determines the interpreter's capture of key information, while the visuospatial sketchpad typically plays a role in analyzing the speaker's body language or visual materials. In consecutive interpreting, many note symbols rely on the activation of encoded information through the phonological loop and visuospatial sketchpad. Whether in simultaneous or consecutive interpreting, the central executive system needs to coordinate and allocate attention when switching between the source language and the target language, reducing the interference of irrelevant information. Therefore, interpretation is a complex activity which integrates input and output, requiring deep involvement of working memory.

Researchers made many conclusions regarding the relationship between working memory and interpreting performance. Zhang Wei (2010) argued that stronger working memory capacity corresponds to better consecutive interpreting performance under equal conditions. Due to the significant impact of second language learners' proficiency levels and training experience on interpreting performance, Liu Yuhua and Dong Yanping (2020) focused their research on interpreting activities at the primary stage, finding that working memory span plays an important role in the primary-stage interpreting activities. Moreover, studies have shown that interpreting training can enhance working memory. For instance, in Chmiel's (2018) study, professional interpreters had a higher reading span than student interpreters before receiving interpreting training; however, after two years of interpreting training, the reading span of student interpreters became indistinguishable from that of professional interpreters. The effect of interpreting practice on working memory may provide insights for second language teaching practices.

4. Conclusions

This study reviews the theoretical development and practical applications of working memory in the second language acquisition, revealing the relationship between working memory and listening comprehension, reading comprehension, second language writing, and interpreting activities. The development and application of working memory models in second language acquisition indicate that the mastery of second language skills requires the combined roles of the phonological loop, visuospatial sketchpad, central executive system, and episodic buffer. Therefore, future research can integrate multimodal teaching methods, design more refined experiments, and discuss the impact of working memory from a dynamic perspective.

Although the results of many empirical studies indicate an association between working memory and the acquisition of the four specific second language skills mentioned above, some studies have shown that working memory does not play a significant role. In order to explore the complex mechanisms by which working memory influences the second language acquisition, subsequent research can focus on approaches such as standardized measurement methods and individual difference analysis.

Furthermore, second language acquisition and working memory mutually influences each other. Teaching practices have proven that interpreting training can enhance working memory capacity. Therefore, future research can concentrate on the promoting effects of different specialized training on working memory capacity, providing more credible and feasible suggestions for teaching practice.

References

- [1] Baddeley, A. D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology: General*, 129(1), 126–145.
- [2] Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation*, 8, 47–89.
- [3] Cao, Y. (2015). Prefabricated chunk acquisition and teaching exploration under the theory of working memory. *Heilongjiang Higher Education Research*, 8, 170–173.
- [4] Chmiel, A. (2018). In search of the working memory advantage in conference interpreting – Training, experience and task effects. *International Journal of Bilingualism*, 22(3), 371–384.
- [5] Fay, A., & Buchweitz, A. (2014). Listening comprehension and individual differences in working memory capacity in beginning L2 learners. *Porto Alegre*, 7(1), 113–129.
- [6] Glass, A. L., Millen, D. R., Beck, L. G., & Eddy, J. K. (1985). Representation of images in sentence verification. *Journal of Memory and Language*, 24(4), 442–465.
- [7] Gu, S. S., & Wang, T. S. (2007). Study on the relationship between working memory and EFL listening comprehension. *CELEA Journal*, 6, 46–56.
- [8] Harrington, M., & Sawyer, M. (1992). L2 working memory capacity and L2 reading skill. *Studies in Second Language Acquisition*, 14(1), 25–38.
- [9] Juffs, A. (2004). Representation, processing and working memory in a second language. *Transactions of the Philological Society*, 102(2), 199–225.
- [10] Kellogg, R. (1996). A model of working memory in writing. In C. Levy & S. Ransdell (Eds.), *The science of writing: Theories, methods, individual differences and applications*. Erlbaum.
- [11] Kong, H. (2024). The interactive effects of working memory and anxiety on ESL learners' reading performance. *Journal of Southeast University (Philosophy and Social Science)*, 1, 141–146.
- [12] Li, H. (2007). The relationship between working memory and attention in the cognitive process of second language learning. *Journal of Southwest Minzu University (Humanities and Social Sciences Edition)*, 2, 199–202.
- [13] Li, S. (2023). Working memory and second language writing: A systematic review. *Studies in Second Language Acquisition*, 45(3), 647–679.
- [14] 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(4), 861–883.
- [15] Liu, H., & Yan, H. (2017). Effects of working memory on individual differences in L2 listening comprehension. *Modern Foreign Languages*, 2, 213–222+292.
- [16] Liu, Y., & Dong, Y. (2020). A longitudinal study of the relationship between early-stage interpreting and working memory. *Journal of Foreign Languages*, 1, 112–121.
- [17] Londe, Z. C. (2008). Working memory and English as a second language listening comprehension: A latent variable approach (Doctoral dissertation). University of California.
- [18] Mavrou, I. (2020). Working memory, executive functions, and emotional intelligence in second language writing. *Journal of Second Language Writing*, 50, 100758.
- [19] Miao, L. (2022). A multidimensional investigation of the relationship between working memory and second language reading comprehension. *Foreign Language Learning Theory and Practice*, 3, 85–93.
- [20] Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the structure of behavior*. Holt, Rinehart & Winston.
- [21] Ni, J. (2017). A study of the influence of working memory capacity on L2 reading ability. *Foreign Languages Bimonthly*, 3, 79–85+160.
- [22] Rahimi, A. H. (2012). On the role of strategy use and strategy instruction in listening comprehension. *Journal of Language Teaching and Research*, 3(3), 550–559.
- [23] Taguchi, N. (2008). The effect of working memory, semantic access, and listening abilities on the comprehension of conversational implicatures in L2 English. *Pragmatics and Cognition*, 16(3), 517–539.

- [24] Wang, E. (2007). The relationship between working memory and learning ability. *Chinese Journal of Special Education*, 3, 78–84.
- [25] Wang, Y., & Cui, G. (2024). Effects of processing and storage elements in working memory capacity on comprehension of different levels in EFL reading. *Foreign Languages Bimonthly*, 2, 83–91+159–160.
- [26] Wang, Y., & Cui, G. (2022). The effect of working memory capacity on macrostructure construction in EFL reading. *Foreign Language Teaching and Research*, 2, 239–251+320.
- [27] Wu, W., & Jin, Z. (2005). Working memory and its theoretical model. *Chinese Journal of Clinical Rehabilitation*, 40, 74–76.
- [28] Xu, F. (2017). An overview of working memory research in sentence comprehension of second language acquisition. *Journal of Ocean University of China (Social Sciences)*, 1, 109–115.
- [29] Yi, B., & Ni, C. (2015). The effect of task instruction and working memory on the written language production of Chinese learners of English. *Foreign Languages and Their Teaching*, 1, 56–61.
- [30] Zhang, F. (2010). The role of long-term memory and working memory in interpreting comprehension from the perspective of cognitive psychology. *Technology Enhanced Foreign Language Education*, 5, 74–79.
- [31] Zhang, M., & Shen, Y. (2002). The review of study on the relationship between working memory and comprehension. *Journal of Northeast Normal University (Philosophy and Social Sciences Edition)*, 2, 121–127.
- [32] Zhang, W. (2010). A review of researches into the memory mechanisms in simultaneous interpreting. *Journal of Foreign Languages*, 2, 60–66.
- [33] Zhang, X. (2014). Influence of short-term memory, working memory and lexical knowledge on L2 listening and reading comprehension. *Foreign Language World*, 5, 38–47.
- [34] Zhang, X., & Chen, Y. (2014). Influence of memory components on L2 listening comprehension. *Modern Foreign Languages*, 3, 360–369+438.