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Working Memory and Second Language Learning: A Review of the Past Twenty Years' Research in China

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This paper systematically reviews the studies of working memory in second language learning in China over the past 20 years. A total of 140 studies that were published in 13 major foreign language journals during the past 20 years (2000-2019) were categorized and analyzed according to research method, educational level, and research content. For research method, two phases could be identified: from 2000 to 2006, more attention focused on introducing theory and reviewing literature regarding the association between working memory and second language learning; and from 2007 to 2019, there is a growing body of quantitative and qualitative research. For educational level of the 75 empirical studies, the majority were targeted at adult learners, whose L2 proficiency was assumed to be at or beyond intermediate level. For the research content, they were classified into three dimensions: L2 understanding, L2 output, and the integration of L2 understanding and output. These three dimensions were sub-divided into a total of seven aspects: vocabulary, grammar, listening, reading, speaking, writing, and interpretation. Considerable advances have been made in the knowledge of working memory and second language learning. Nevertheless, more research is needed to develop a deeper understanding of the interrelationships between working memory and different domains of second language learning.

Keywords: working memory, second language learning, literature review

1 Introduction

Working memory is generally understood as a limited-capacity processing and storage system that is necessary for carrying out a wide range of cognitive tasks (Baddeley, 2003). Working memory capacity is defined as the ability to store information and manipulate it simultaneously. There is a

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massive amount of information that comes into our sensory memory every day; however, it is impossible to process all of it at the same time. Some information is selected and passed along into working memory to be processed. Therefore, working memory is the sum of the information temporarily stored in human consciousness and all online processing.

With the above characteristics, working memory is considered to be important for second language learning. All aspects of second language learning involve information storage and processing, and working memory plays an important role in advanced and complex cognitive activities (e.g., speech, learning, computation, understanding, reasoning). More and more second language researchers have conducted empirical studies on the possible effects of working memory on different domains of L2 learning and processing, covering reading, listening, writing, speaking, and interpreting (for comprehensive meta-analysis, see Linck, Osthus, Koeth, & Bunting, 2014; Watanabe & Bergsleithner, 2006; Wen, Mota, & McNeill, 2013).

In the past two decades in China, the field of second language learning has paid constant attention to working memory, and the study of this topic has grown significantly. This study sets out to review in detail the information in papers published during the past 20 years (2000-2019) in 13 major foreign language journals in China. The overall aim of this study is to answer the following four questions:

(1) What is the general trend of second language research on working memory in China in the past 20 years?
(2) What are the research methods employed in these studies?
(3) What are the research contents of these studies?
(4) What are the problems revealed in the current research practice and what deserves more attention in the future?

2 Working Memory and Second Language Learning

For most working memory research, Baddeley's model of working memory (Baddeley, 2000) serves as the framework for explaining the specific functions of each working memory component (see Figure 1). According to this model (Baddeley, 2000), working memory is comprised of four components which process distinct types of input information. Auditory information is stored and processed by the phonological loop, while the visuospatial sketchpad is responsible for visual images and spatial relations. The central executive plays a role similar to a traffic cop who regulates the other components of working memory and allocates cognitive resources. The episodic buffer is assumed to be the storage component of the central executive, and a link from working memory to long-term memory. In the information processing model, long-term memory is the final stage.

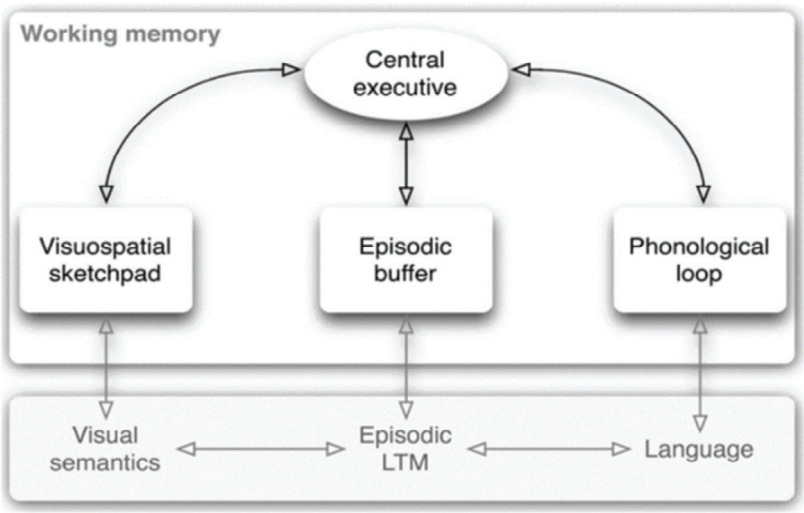

Figure 1. Baddeley's component model of working memory (Baddeley, 2000)

Previous research has established the vital role played by working memory in the development of different second language stages and second language skills (Baddeley, Gathercole, & Papagno, 1998). The research investigating working memory and second language chunks and collocations (Ellis, 1996, 2012); second language interaction (Mackey, 2012; Révész, 2012); bilingual processing and interpretation (Christoffels, Groot, & Kroll, 2006); second language grammar skills (Verhagen, Leseman, & Messer, 2015); and second language morphosyntax (Serafini & Sanz, 2015) has enriched our understanding of the relationship between working memory and second language learning.

Specifically, there are numerous empirical studies that demonstrate the close association between the central executive component of working memory and complex cognitive skills (listening, speaking, reading, writing) engaged in second language learning process (e.g., Ellis & Sinclair, 1996; Martin & Ellis, 2012; Service, 1992), and its effective inhibition of negative transfer from first language (Linck et al., 2014). In addition, the effects of the phonological loop component of working memory are not only evident in first language learning but also second language learning (Baddeley, 2015). So far, the visual and spatial working memory and the episodic buffer working memory in Baddeley's model have not attracted relatively as much attention from second language researchers. It could be seen that the relationship between the different components of working memory and second language learning is far from well-established.

3 Methodology

A quantitative research-based approach was chosen to review the literature on the relationship between working memory and second language learning in China. To begin, this paper selected the time span of January 1, 2000 to December 31, 2019, and used "working memory," "working memory capacity," and "working memory model" as key words to search in the CNKI (China National Knowledge Infrastructure). The search tracked 140 related papers written in Chinese that were published in 13 Chinese major foreign language journals in the past 20 years. These domestic foreign language journals are in the Chinese Social Sciences Citation Index for the foreign language field. Accordingly, they comprehensively represent the current situation and development direction of second language research in China. Table 1 lists the 13 journals in alphabetical order and the number of publication papers in each journal.

Table 1. List of 13 Chinese Major Foreign Language Journals

No.	Journal	Paper number
1	Foreign Languages (Waiguoyu)	12
2	Foreign Language and Foreign Language Teaching (Waiyu yu Waiyu Jiaoxue)	13
3	Foreign Language and Literature (Waiguo Yuwen)	9
4	Foreign Languages in China (Zhongguo Waiyu)	5
5	Foreign Language Research (Waiyu Xuekan)	8
6	Foreign Languages Research (Waiyu Yanjiu)	8
7	Foreign Language Teaching (Waiyu Jiaoxue)	13
8	Foreign Language Teaching and Research (Waiyu Jiaoxue yu Yanjiu)	22
9	Foreign Language Teaching Theory and Practice (Waiyu Jiaoxue Lilun yu Shijian)	4
10	Foreign Language World (Waiyu Jie)	6
11	Journal of PLA Foreign Languages (Jiefangjun Waiguoyu Xueyuan Xuebao)	12
12	Modern Foreign Languages (Xiandai Waiyu)	16
13	Technology Enhanced Foreign Language Education (Waiyu Dianhua Jiaoxue)	12

Note. Chinese Pinyin is given in brackets.

After examining the 140 papers manually one by one, 9 papers were rejected due to their low relevance to the topic. The remaining 131 research papers were downloaded from CNKI and imported into NoteExpress

(reference management software) to form a paper database. Then the 131 papers were systematically sorted into empirical studies and non-empirical studies in terms of research method. Based on Wen's categorization of research content (Wen, 2012), the 75 empirical studies were further summarized and analyzed into three dimensions and stored in Excel software. The findings were interpreted from four aspects: general research trend; research method; research content; the problems revealed from the studies.

4 Results and Discussion

4.1 General research trend

Figure 2 shows the frequency distribution of the 131 research papers on working memory and second language learning published in Chinese foreign language journals, according to publication year.

Figure 2. Paper publication frequency from 2000 to 2019

In Figure 2 there is a clear trend showing the increase in the number of published papers in China. The past two decades have seen the rapid development of research in working memory on second language learning. During the first 5 years from 2000 to 2004, no more than 3 papers were published annually, and for a few years (2000 and 2001), the paper publication number was zero. Since 2005, researchers have been increasingly interested in the association between working memory and second language learning. A peak was reached in 2012, with 13 papers published. Due to the development of cognitive science, more and more attention has been given to working memory in the process of language comprehension and production. Working memory has become a new hot topic in second language research.

4.2 Research method

Research issues relating to research method classification, educational background of participants, and measurement tools for working memory are outlined and clarified in this section. Research papers are presented in research method to illustrate an overview of the empirical studies and non-empirical studies. The analysis of the participants' educational level contributes to an understanding of Chinese scholars' research focus. Then, the measurement tools of working memory are summarized to identify what tools are most used by Chinese scholars.

4.2.1 Empirical research and non-empirical research

The present study categorized the 131 papers with regard to research method. First, the papers were roughly divided into two categories: empirical research and non-empirical research. Empirical research refers to the method of collecting data and inductive analysis by conducting experiments, observations, and questionnaire surveys, and constructing corpora on research themes. Non-empirical research basically consists of theoretical introductions and literature reviews.

The statistics (see Figure 3) show that there are 56 non-empirical papers (theory introduction, theoretical interpretation, theoretical review), accounting for 42.75% of the total; and 75 empirical research papers, accounting for 57.25%. A turning point was marked in 2009, the number of empirical studies started exceeding the number of theoretical studies. The number of empirical research papers reached the peak in 2012, with 10 papers (76.92%) in that single year.

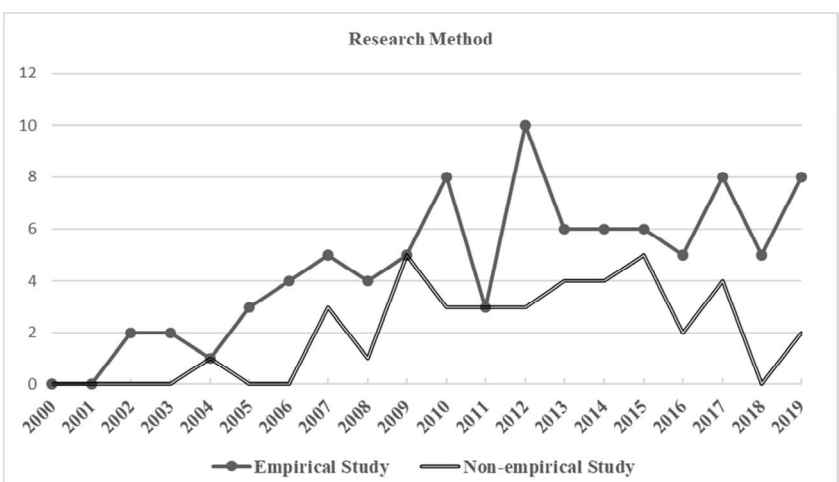

Figure 3. Paper publication frequency in empirical and non-empirical research from 2000 to 2019

It can be clearly seen from Figure 3 that in the study of working memory in second language learning there were two distinct phases regarding research method. The first phase (from 2000 to 2006) was the exploration period in which non-empirical research dominated (only one empirical study); the second phase (from 2007 to 2019) was the development period, and the research focus underwent a complete transformation: the number of empirical research surged, and surpassed non-empirical research. This phenomenon can be largely attributed to a shift in emphasis of second language research from language itself to language learners. Exploring learners' cognitive characteristics to obtain in-depth information on the nature of language is a continuing concern (Wen & Yi, 2015).

4.2.2 Educational level

In line with the classification scheme of Wen Qiufang and Wang Lifei (2004), the participants of 75 empirical research papers were analyzed by their educational backgrounds. The studies mainly cover the following educational groups: primary school students, middle school students, high school students, undergraduates, postgraduates, and English professional interpreters. The results are presented in Figure 4.

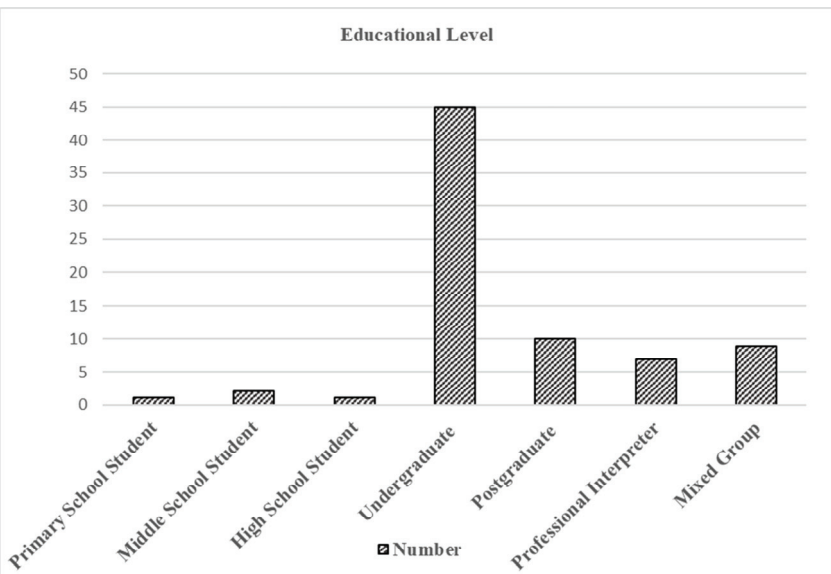

Figure 4. Educational level of participants

It is apparent from Figure 4 that researchers focused more on college students (undergraduates), with 45 studies accounting for 60% of the total. With the exception of Jiang, Xie, and Meng (2015), who specifically targeted elementary students; Dai (2011, 2014), second-year middle school students;

and Liu and Xu (2014), third-year high school students, adult learners (undergraduates, postgraduates, and professionals) have been the subject of 71 studies. This may be due to the researchers' working environment. The researchers engaged in relevant research are mostly concentrated on higher education, and it is more convenient for them to study college students.

Most mixed-type group research involved comparative studies of language interpretation, in which working memory capacity and interpretation skills were measured and compared between groups of learners with different educational backgrounds and, more importantly, with different English proficiencies. For example, in Zhang's study (2009), there were three types of participants: 35 lower-level interpreters (English major students), 35 upper-level interpreters (English major students), and 13 professional interpreters. In their qualitative study, Shen and Liang (2015) interviewed four participants, including two English major students and two professional interpreters.

Educational background is undoubtedly related to age and second language proficiency. As for college students, the age group mostly ranges from 17 to 25 years old, and their English proficiency is supposed to be at or beyond intermediate level. Over 20 years old, postgraduates and professional interpreters are beyond intermediate level of English proficiency. Obviously, interpreters are more exposed to an English environment than learners from other educational backgrounds. In the sample studies, professional interpreters refer to full-time interpreters with systematic interpretation training, and they are considered to be advanced learners with native-like L2 proficiency.

It is reasonable to assume that educational level is an important factor in the analysis of the relationship between working memory and second language development. The role and function that working memory plays at different stages of L2 learning development might be divergent. As suggested by Gass and Valmori (2015), learners' L2 level should not be ignored in research design, in order to adopt exact working memory measurement tools more scientifically.

4.2.3 Measurement

The empirical studies generally relied on cognitive psychological methods using experimental design paradigms and working memory measurement tools. Table 2 is the summary of the most common working memory measurement tools employed by Chinese second language scholars.

Table 2. Working Memory Measurement Tools

Task type	Designer	Year	Task name
Simple Memory	Congway	1996	Word span test
	Nassaji	1999	Phonological awareness test

Span Task	Ariji et al.	2003	Digit span test
	Helland Asbjmsen	2004	Digit span test
Complex Memory Span Task	Daneman and Carpenter	1980	Reading span test
	Waters and Caplan	1996	Reading span test
	Unsworth et al.	2005	Reading span test
	Turner and Engle	1989	Operation span test
	Forster	2003	Operation span test

Simple working memory span tasks refer to measurements that directly examine the storage function of working memory only, while complex working memory span tasks encompass more complex functions (i.e. storage and processing) of working memory (Wen, 2018). More precisely, the simple task assesses the phonological loop of the working memory, and is based on word or non-word recognition and repetition. Complex tasks are typically designed with dual tasks (information storage and information processing) in parallel.

Daneman and Carpenter's reading span test (1980) was widely adopted by Chinese researchers, accounting for 36% out of the working memory span task pool. In the standard version, participants are required to judge the acceptability of sentences while simultaneously trying to remember the final words of sentences. This task has been developed into different versions (digit span test, listening span test, operation span test, etc.) for processing tasks in various activities of second language learning. The operation span task is the updated version of the reading span task (Daneman & Carpenter, 1980), which comprises a mathematic test and a word memorizing test. For instance, in Turner and Engle's operation span test (1989), participants are asked first to solve simple mathematical equations (which aims to tap into the processing component of working memory), then recall a string of letters (for the storage component).

Working memory measurement tools were originally created in cognitive psychology. As a result, their effectiveness may fail to adequately apply to second language learners. For example, in the selection of language for the working memory task, whether to choose learners' native language or second language for testing, and the distinction between the two languages need more consideration. Specific to the working memory task, some studies have shown that diverse research results may derive from the design of working memory span tasks (Ji & Li, 2018; Qin & Liu, 2016; Xu, 2011).

4.3 Research content

Based on the classification of research content from Wen (2012), the 75 empirical papers were sorted into three dimensions: L2 understanding, L2

output, and the integration of L2 understanding and output. These three dimensions were sub-divided into seven aspects: vocabulary, grammar, listening, reading, speaking, writing, and interpretation. The classification of the research content of the 75 empirical papers is summarized in Table 3.

Table 3. Research Content Classification

Dimension	Aspect	Papers		Percentage	
L2 understanding	vocabulary acquisition	8	41	10.67	54.67
	grammar/syntax acquisition	15		20.00	
	reading/discourse/sentence understanding	11		14.67	
	listening comprehension	7		9.33	
L2 output	writing	7	12	9.33	16.00
	speaking	5		6.67	
Integration of L2 understanding and output	interpretation	18	18	24.00	24.00
Others		4	4	5.33	5.33

According to the statistics in Table 3, there are 41 studies (54.67%) from the perspective of L2 understanding, accounting for the largest proportion; 12 studies (16%) investigating the association of working memory and L2 output; and 18 studies (24%) relating to the dimension of the integration of L2 understanding and output.

As Table 3 demonstrates, most of the studies have attempted to quantify the influence of working memory on grammar/syntax acquisition; reading/discourse/sentence understanding; and interpretation. It happens that these studies are more concerned with the role of working memory in the speed of second language information extraction, second language interaction, offline understanding, online understanding, and performance of second language skills. The following subsections will discuss the findings of the studies in each of the three aspects of second language learning.

4.3.1 L2 understanding

According to Wen (2012), vocabulary, grammar, syntax, reading (discourse and sentence understanding), and listening form L2 understanding. Many of the current studies (54.67%) pay particular attention to the link between working memory and L2 understanding.

There is a consensus view (either implicitly or explicitly) on the critical role of working memory in L2 grammar and syntax acquisition. To determine this issue, Chen and Gao (2009) explored how adult learners'

working memory capacity inhibited second language grammar processing. The result showed that the grammar judgment scores of participants with high working memory were significantly higher than those with low working memory capacity. It confirms that second language grammar processing was affected negatively by low individual working memory capacity. The role of working memory and teaching methods in the acquisition of English relative clauses was investigated in Dai's study (2011). Explicit and implicit teaching methods were used to teach four relative clauses, and a test was conducted immediately after teaching. When learners' working memory capacity was high and medium, the relative clause was learned better than for learners with low working memory capacity. Chang, Xu, and Wang (2017) also supported the significant effect of working memory on the processing speed of L2 syntax.

With respect to working memory and L2 vocabulary learning, Ni (2018) produced a key study comparing factors influencing working memory. In this study, the working memory capacity was measured by the reading span test, and L2 vocabulary ability was evaluated by a vocabulary ability test of vocabulary reading accuracy and processing time. Working memory capacity declined when either vocabulary letters and/or syllables increased or when the memory content and recall time lengthened. L2 vocabulary ability is correlated with working memory capacity, especially, its storage function.

The effect of grade/age/L2 proficiency is another factor which could not be overlooked in the study of working memory and L2 vocabulary learning. When the subjects were English major undergraduates, little evidence of a linear relationship between working memory and L2 vocabulary was discovered (Li, 2004). Jiang et al. (2015) devoted some attention to fourth and fifth grade elementary students, and identified that the mechanism for the inhibition of irrelevant information and the development of English vocabulary by lexical semantic extraction were restricted by working memory capacity and cognitive constraints. This rather contradictory result may be due to the difference in participants' grade/age/L2 proficiency.

Another conflicting result comes from Li and Li (2007), which showed that individual differences in working memory capacity had no restrictive effect on the semantic extraction process. Moreover, they pinpointed that the second language semantic extraction was a relatively automatic process. However, their working memory measurement tools were mathematical operations and Chinese double words. This indicates that there are obvious difficulties in accepting the reliability of their specific working memory measurement tools.

Second language reading comprehension is an active interaction between the information from the input text and the information from readers' schema, involving complex cognitive processes. Aside from finding a correlation between working memory and second language reading performance, researchers have also paid attention to reading material types

and components of phonetic awareness. For instance, text comprehension and working memory were found to be positively correlated, but this was not strictly linear and was affected by schema activation (Zheng, 2015). Gui (2018) inspected six components of reading (semantic processing, syntactic processing, text structure, strategy processing, phoneme processing, and working memory). Compared to semantic processing, syntactic processing, and text structure, working memory had less influence on reading comprehension, the correlation analysis showed that phoneme processing, working memory, and reading comprehension were positively correlated.

Recently, initial efforts were made by Chinese second language scholars to probe the role of working memory for L2 listening. Liang's study (2009) found that participants' working memory capacity was an effective predictor of their listening comprehension scores. In listening comprehension, the illustration of graphic images could reduce the load of working memory, so that listening comprehension performance was improved with the help of efficient representations/images (Li & Yu, 2009). Furthermore, Liu and Yan's study (2017) suggested that storage capacity, processing accuracy, and processing speed in L2 listening were positively correlated with working memory capacity.

In contrast, some researchers claimed that working memory had no explanatory power for L2 listening skills. Zhang, Liao, and Chen (2018) argued for the weak correlation between short-term digital memory, computational working memory, verbal working memory, and L2 listening comprehension. In their study, working memory was measured by the digit task and word span task instead of more complex working memory span tasks (e.g., reading span task, operation span task). Alternatives of working memory measurement tool might explain the discrepancy in some research findings.

4.3.2 L2 output

In the present study, L2 output consists of speaking and writing performance. Despite the differences in the number of specific measures included in individual studies, most researchers have utilized the theoretical framework advocated by Skehan (1998) to index L2 speech and written outcomes, incorporating complexity, accuracy and fluency.

Working memory has been identified as a major contributing factor to oral fluency and accuracy. In a large scale study (120 non-English major students) by Jin (2012), for example, the regression results showed that working memory capacity and L2 fluency and accuracy were significantly correlated, but no correlation was found with the complexity of spoken language. In addition, the influence of working memory capacity on L2 oral fluency was restrained with the improvement of L2 proficiency (Han, 2015). In light of this, as long as the automation degree of spoken language output coding has been reinforced, the demand for working memory resources

would be weakened. Han, Cui and Tang (2017) clarified that working memory influenced the fluency and accuracy of oral production, and high task frequency could improve the accuracy, complexity, and fluency of oral production.

In another recent study, to scrutinize the connections between working memory and learner factors in L2 oral performance, Wang (2019) carried out a structural equation model study. The study used questionnaires and test tools to explore the interaction between oral English performance and the six learner factors (i.e. emotional intelligence, foreign language anxiety, learning motivation, working memory, linguistic ability, and cognitive style). From the structural analysis, working memory, linguistic ability, and cognitive style ranked as the most influential learner factors on oral performance, followed by foreign language anxiety, cognitive ability, and emotional intelligence.

Compared with oral output research, studies of the influence of working memory on L2 written performance have focused only on the aspect of accuracy. Huo and Wang (2011) tested Kellogg's [1] (1996) working memory model for the L2 writing process by analyzing working memory reaction time, working memory reaction accuracy, and L2 written output. They stressed that participants' working memory capacity correlated highly with the accuracy of written output and syntactic complexity. The task complexity was negatively correlated with syntactic complexity in learners' written output. In addition, the phonological loop and visuospatial sketchpad components of working memory participated in "transfer" and "plan" in the writing processes. Likewise, Yi and Luo (2012), and Yi and Ni (2015) asserted a causal relationship between working memory and L2 written output accuracy, and found little impact on the fluency and complexity of written output.

4.3.3 Integration of L2 understanding and output

On the integrated dimension of language understanding and output, studies were primarily concerned with simultaneous interpretation. The results of recent studies have been encouraging and consistent, confirming that high working memory capacity facilitated learners' general L2 understanding and output. As a more complicated activity, simultaneous interpretation involves taking in information, processing information, then producing information, and this is proven to be more related to working memory. When learners are working with unknown information, their working memory bears much more strain/load. In contrast, when they have sufficient skills or knowledge for the task, the strain/load of working memory will be less, and they may devote

[1] Kellogg's model of written production is divided into three sub-stages: formulation, execution, and monitoring (see Kellogg, 1996: 59).

more storage function to processing that task. Therefore, learners' world-knowledge and targeted skills may support the efficiency of working memory.

Zhang (2009, 2012) declared that the higher the working memory capacity, the better the simultaneous transmission ability, and the coordination of memory resources was greater than that of memory capacity. Similarly, Kang (2016a) suggested that working memory was closely related to the semantic priming of long-term memory, indicating that storing a large amount of long-term memory information and encyclopedic knowledge may be beneficial to interpretation.

In a series of correlational/comparative studies, research efforts were extended to the target language and L2 proficiency. Zhang (2014) conducted a two-way English-Chinese, Chinese-English interpretation test and a listening span test with 30 English major students. The results indicated that participants' working memory capacity was quite correlated with their Chinese-English interactive interpretation performance, but not with English-Chinese interactive interpretation performance. At the same time, the performance of participants' English-Chinese interactive interpretation performance and Chinese-English interactive interpretation performance were highly correlated.

In a recollection experiment with professional interpreters, master of translation and interpreting students, and non-English major students, Kang (2016b) noticed that compared with professional interpreters, student interpreters had a much smaller working memory span for simultaneous interpretation. Li and Cao's study (2018) echoes this previous research, and found low level translators' working memory capacity was obviously lower than intermediate translators', providing evidence that cognitive training (interpreting practice) might be helpful.

For a long time, the study of interpretation has centered on the cognitive processing of interpretation, but the real object of the interpretation process is information. To fully describe and explain the behavior of interpretation, the exploration of cognitive processing and instant bilingual information processing needs to be addressed further. This view is supported by Shen and Liang (2015)'s study, which showed that working memory influenced simultaneous interpretation in cooperation with some non-working memory factors (including professional knowledge, conversion speed, and interpretation rhythm).

More recently, Liu and Mei (2019) compared the difference between translators' and non-translators' working memory by analyzing the characteristics of simultaneous listening and discriminative comprehension. The experimental results reflected that translators' cognitive advantage was embodied in the efficient interaction of long and short-term memory (i.e. the rapid construction of the explicit situation model), but this ability cannot be extended to the implicit situation model which only contains the verbal information. Under the multi-task condition of the situation model

construction, translators still have unrecognized cognitive resources, proving the construction of the explicit situation model did not consume too many resources, and automatic processing might take place in a certain degree.

4.4 Critique of current studies

Regarding measurement tools and research methods in empirical research, there are some issues worthy of reflection and improvement. First, the bias of research towards sampling only a single education level (e.g., only undergraduates) might result in a lack of diversity of participants' English proficiency within the study. The influence of working memory on second language learning and processing varies with L2 proficiency and learners' age. The narrow range of age or educational level in studies fails to explore how working memory operates differently at the distinctive stages of second language learning.

Second, the academic community has not reached a consensus on whether working memory is domain specific or domain independent, making the use of measurement tools inconclusive (Wen, 2018). The selection of working memory measurement tools should be more cautious to ensure the reliability and validity of relevant research and to improve the comparability of research results.

Third, in the studies, another limitation that stands out is the absence of neurophysiological research methods. It could be concluded that most of the empirical research in China falls short of experimental psychology, psychometrics, and brain imaging technology (fMRI, ERP, the neuroscience of PET, etc.) in research design. The interdisciplinary field should combine applied linguistics and cognitive sciences to have a fuller picture of working memory (Wen, 2018).

Finally, the vast majority of working memory research is from the view of synchronic observation. Few studies have used longitudinal tracking methods to study the dynamic changes of working memory. If the chronological changes of working memory can be observed, this will help develop a deeper understanding of the nature and mechanism of working memory.

5 Conclusion

To sum up, Chinese scholars' interest in working memory and second language research has surged since the beginning of the 21st century, and it has developed steadily in the past two decades. Recent years have witnessed an increasing number of empirical studies in second language learning pointing to the important role of working memory in various aspects of L2 learning. A number of empirical studies have yielded convincing research

findings. The research results present that consensus is greater than divergence, and this has confirmed that the main function of working memory is not memory itself, but a multi-component, multi-functional cognitive resource system dominated by executive functions (Wen & Yi, 2015).

The results of the present study have provided the sufficient information about the significance of working memory in second language learning. Therefore, it is effective that teachers choose some tables, flowcharts, schematics, timetables or multimedia presentation to help learners perceive information by stimulating multi-dimensional neural connections temporarily. Besides, reiteration, retelling, reading aloud or silent reading could strengthen the retention of the information acquired through short-term memory. When a conditioned reflex is formed, the information is inclined to be stored in long-term memory. As working memory capacity is limited, the expansion of prefabricated chunk storage could save as much space in brain as possible to memorize more new information, and speed up the response of the brain, so as to achieve a better efficacy of working memory. At the same time, teachers should also speak slowly and clearly in teaching, using concise and clear sentences, and avoid presenting too much information at once to release the load of working memory.

Overall, the gaps in the previous studies reveal that issues on the different components and functions of working memory in the various levels and stages of second language learning require researchers to carry out a large number of empirical studies. By improving research design, expanding research methods, conducting diachronic follow-up research, and combining specific aspects of L2 learning, further future studies will be able to disclose a comprehensive understanding of the role of working memory for second language learning.

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