

WORKING MEMORY AND SECOND LANGUAGE READING COMPREHENSION:
IMPLICATIONS FOR LEARNING CHINESE IN ENGLISH MEDIUM
INTERNATIONAL SCHOOLS IN THAILAND - A META-SYNTHESIS

by

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Abstract

Working Memory (WM), as defined by Baddeley et al. (2021), is “a limited capacity system for the temporary maintenance and processing of information in the support of cognition and action” (p.10). Acknowledging the pivotal role of WM, it becomes evident that the disorders in this cognitive system will impact language processing. This meta-synthesis delves into the intricate relationship between WM and second language (L2) reading comprehension with a specific focus on its relevance for Grade 9-12 students engaged in the acquisition of Mandarin Chinese as an L2 within the context of English medium international schools in Thailand. This systematic review of literature presents a comprehensive synthesis of existing research literature spanning from 2004 to 2023, synthesizing key findings to shed light on the cognitive process underlying L2 reading comprehension within an inclusive educational setting. Research findings reveal that the phonological and visuospatial components of WM have been found to significantly influence L2 reading comprehension outcomes, with individual differences playing a crucial role in shaping these effects. Despite the limitations, the research empowers educators with practical insights to optimize Mandarin Chinese L2 comprehension outcomes of a diverse group of students in an inclusive learning environment.

Keywords: working memory, second language learning, L2 reading comprehension, Mandarin, Chinese, literature review

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Chapter One: Introduction

Incorporating neurodivergent learners in an inclusive educational setting, particularly within the realm of second language (L2) instruction, presents distinct challenges. Hence L2 educators increasingly acknowledge the critical significance of recognizing individualized differences. This recognition is aligned with a broader commitment to promoting equity in the language learning environment. L2 educators have identified an array of cognitive hurdles within the classroom setting that encompass conditions like dyslexia, attention-deficit/hyperactivity disorder (ADHD), autism, and more. These conditions exert notable influence on language acquisition, albeit through diverse avenues. In the sphere of constrained working memory (WM) capacity, individuals often encounter variant obstacles in their efforts to grasp and process language knowledge. This challenge arises from the pivotal role that WM plays in both retaining and processing language input, as well as facilitating engagement in comprehension and production tasks.

Historically, educators studied language and memory as separate cognitive abilities (Duff & Piai, 2020) for a long time. However, the emergence of the seminal multi-component model of Baddeley and Hitch (1974) marked a critical turning point. This model ignited a surge of research enthusiasm to probe the fundamental cognitive functions that support the learning of both first and second languages. Harrington and Sawyer (1992) also revealed a noteworthy relationship between L2 WM reading span and L2 reading comprehension scores. This discovery sparks extensive exploration of the relationship between WM and L2 reading by scholars in the field of cognitive-oriented second language acquisition (SLA). Baddeley (2015) recently acknowledges that “the most successful contribution of the framework of WM was to language learning, principally to the acquisition and development of vocabulary in children and also to L2 learning” (p.17).

Mandarin Chinese (referred to as Chinese below) holds a prominent position as one of the most extensively studied L2 in the world, particularly in Asian countries and regions. In this context, it is commonplace for many English-medium international schools in Thailand and various other Asian countries or regions to include Chinese as one of their world language offerings in the curriculum. These international schools typically introduce Chinese as an L2 subject for high school students, commencing from Grade 9 to Grade 12. The inclusion of Chinese learning is consistent with the overarching mission of English medium international schools, which is to furnish students with a holistic education geared towards preparing them for active participation in the increasingly globalized world. Moreover, adolescence signifies a crucial developmental phase characterized by significant advancements in cognitive abilities and other domains. This developmental stage can offer distinctive advantages for L2 learning, making it an opportune time for students to embark on their journey of acquiring Chinese as L2.

However, taking into account the diverse characteristics and needs of individual students and the inherent complexities of Chinese, some Grade 9-12 students learning Chinese as L2 have encountered diverse challenges, particularly in the domain of reading comprehension. Extensive research demonstrates that “WM, as one of the main executive function components, is a “determinant of reading comprehension” (Seigneuric & Ehrlich, 2005, p. 648). Given this connection, it becomes imperative to probe the critical relationship between WM and L2 reading comprehension, especially for students who grapple with the simultaneous processing and retaining of information while reading in their L2.

The primary objective of this study is to explore the relationship between WM and L2 reading comprehension by conducting a comprehensive analysis and synthesis of empirical research spanning from 2004 to 2023. One of the sub-aims is to investigate how WM influences L2 reading comprehension across different proficiency levels. The research

hypothesis posits that individuals with higher proficiency levels and larger WM capacity exhibit advantages in L2 reading. Another sub-aim is the examination of the role of visuospatial sketchpad in Mandarin L2 reading comprehension, with a corresponding hypothesis suggesting its impact. Additionally, the study will provide valuable insights into pedagogical practices applicable in inclusive classrooms.

Background and Problem Statement

The intention of this research arises from the experiences of several students in my Chinese as L2 classes. These students dedicate substantial time and effort to their Chinese studies, yet their academic performance does not consistently reflect their diligence. Despite their conscientiousness, they often face difficulties in tasks such as forming Chinese characters, recalling vocabulary meanings, applying syntactic structures in sentences, and grasping the contextual meaning in articles. Considering this discrepancy between effort and outcome, it becomes important for educators to acknowledge and address these issues, striving to create a more equitable and effective learning environment within the Chinese L2 classroom. Proficiency in L2 reading comprehension holds profound significance in the broader context of L2 acquisition. Therefore, as a Grade 9-12 Chinese L2 teacher in an English medium international school in Thailand, it is not just a responsibility but also a calling to commence this research endeavor. Through a comprehensive examination of existing research, with a primary emphasis on exploring the relationship between WM and L2 reading comprehension, this study also seeks to gain insights that can inform potential solutions and strategies to provide pedagogical support for students who encounter challenges in retaining and processing information, particularly in the realm of Chinese as an L2 reading comprehension.

Introduction to Key Concepts

Executive Functions

WM is considered to be one of the key Executive Functions (EFs). EFs constitute a set of advanced cognitive processes and mental skills that exert control over thoughts, emotions, and actions. These EFs are typically classified into three primary categories: WM, Inhibitory Control, and Cognitive Flexibility. Research conducted underscores “the important role of EFs in the development of academic competence, including reading, vocabulary acquisition, and the comprehension of both oral and written language” (Follmer, 2018, p.42). Seigneuric and Ehrlich (2005) prove that “WM capacity was a direct predictor of reading comprehension when contrasted with vocabulary and decoding skills” (p.642). Lately, Georgiou et al. (2020) report that “all three EF components correlate significantly with reading and mathematics performance” (p.3).

Working Memory (WM)

As one of the three component sub-skills of EFs, WM comprises a cognitive system with a limited capacity that can hold information temporarily within the brain for further utilization and evaluation to accomplish a task. WM holds particular significance in tasks that demand reasoning abilities and it also exhibits influence over decision-making processes and behavior. Juffs and Harrington (2011) proclaim that “WM is better understood as a part of cognition rather than as a part of memory” (p.138).

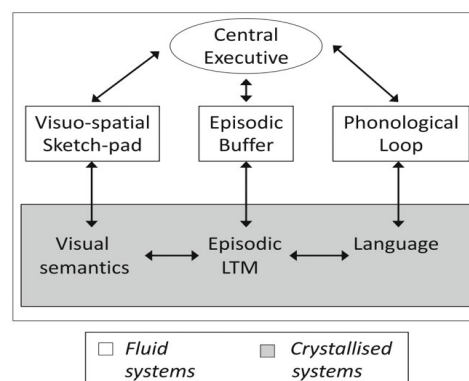
Since Baddeley and Hitch (1974) proposed the most seminal and influential multi-component model of WM, it underwent several developments and extensions by Baddeley (2000) to specify the functions of the central executive. According to the model of WM that Baddeley (2000) updates, there are four subcomponents of WM: central executive, phonological loop, visuospatial sketchpad, and episodic buffer. The central executive, as the

attention-controlling system, integrates and coordinates the slave systems. Both the phonological loop and the visuospatial sketchpad serve as slave systems for the short-term storage of information. The phonological loop, the verbal component of WM, temporarily stores and rehearses speech-based information, and is necessary for the acquisition of both native and L2 vocabulary. The visuospatial sketchpad manipulates visual and spatial information, and it helps to generate and temporarily store images. The episodic buffer, which was added as a new component of WM by Baddeley in 2000, helps to integrate information from a range of sources into a multidimensional code.

“The components of WM are independent of each other and draw on different pools of resources” (Li, 2023, p.349). Moreover, each component of WM has its own specific function to cater to the efficiency of its performance. This WM model, since its inception in 1974 and extension in 2000, has demonstrated itself to be an exceedingly valuable framework for L2 acquisition, as Wen (2012) discusses that “different components of WM are found to be highly correlated with different aspects of L2 performance and development and with specific L2 skills development” (p.17). Therefore, researchers around the world adopt the multi-component model of WM and correlate its mechanism with language learning.

Figure 1.1

The Revised Multicomponent Model of Working Memory¹



¹ Note: Adapted from “Attention and binding in visual working memory: Two forms of attention and two kinds of buffer storage,” by Hitch et al., 2020, *Attention, Perception, & Psychophysics*, 82, p.282.

In addition to Baddeley and Hitch's (1974) and Baddeley's (2000) widely recognized models of WM, many other researchers also attempt to explain the essence of WM, resulting in a wide range of theoretical perspectives. As Miyake and Shah (1999) assert, "a variety of models and theories proposed earlier reflect such diverse perspectives on the nature, structure, and functions of WM" (p.2). Another noteworthy theoretical model of WM, which emphasizes a close association between attention and WM, is Cowan et al.'s (2005) embedded-process view of WM. Even though both models aim to explain how WM operates, the theoretical framework of Cowan's embedded-process view of WM has an important difference compared with Baddeley and Hitch's multi-component models of WM. Linck et al. (2014) describe that, "Cowan proposes a two-tier structure for WM, distinguishing a zone of privileged and immediate access - the focus of attention - from activated but not immediately accessible long-term memory (LTM)" (p.5). In contrast to Cowan et al. (2005)'s view, Baddeley and Hitch's model places less emphasis on the role of attention and the environment in WM. Besides the models of WM mentioned above, there are other influential models of WM, seemingly disparate in nature, that attempt to explain the mechanisms of WM, emphasizing diverse perspectives. However, due to the fact that the majority of the research studies included in this meta-synthesis are primarily impacted by the model of WM that Baddeley (2000) proposed, references to the WM model in the following sections will be grounded in the theoretical framework provided by Baddeley (2000).

The Features of the Chinese Language

To investigate the relationship between WM and Chinese L2 reading comprehension, it is crucial to gain a general understanding of the features of the Chinese language. Regarding the spoken form of the language, Chinese consists of various dialects, with Mandarin and Cantonese being the most prominent in Chinese-speaking regions, such as Mainland China, Hong Kong, Singapore, and so forth. In terms of the written form of the

language, both Mandarin and Cantonese share the same writing system. However, there is a distinction in the characters used: Mainland China and Singapore predominantly employ simplified Chinese characters, while Hong Kong, Macau, and Taiwan use traditional Chinese characters. Mandarin Chinese (referred to as Chinese) is the most prevalent variety of Chinese, making it the primary focus of language education. It is widely taught as an L2 in countries or regions that share substantial cultural and economic ties with China, such as Thailand.

Visually, Chinese script is more complex than alphabetic writing systems because each character possesses a number of different strokes that are packed into a square shape. For example, as shown in Figure 1.2, 日, the character is pronounced as rì (/rì /4, this is the Pinyin system, the phonetic guide for Chinese people to pronounce the Chinese characters; the digit number represents one of the four tones in Chinese) and the meaning of this character is sun or day. This character is a pictographic character. The formation of this character was originally from the shape and appearance of the actual sun. The pictogram is one of the formations of ancient Chinese characters.

Figure 1.2

Example of a Chinese pictograph character²



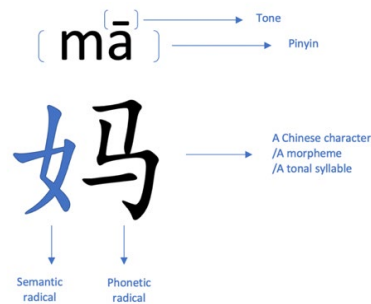
Besides pictographic characters, there are also compound characters. For example, as shown in the Figure 1.3, the character “女” (as shown on the left side), is a simple character, with the pronunciation as nǚ (/nǚ/3), and the meaning of this Chinese character is female.

² Note: Adapt from “A Brief Analysis of Chinese Hieroglyphs in the Zero-based Teaching of Chinese Characters as a Foreign Language,” by Jin, 2021, *Chinese Language and Culture Journal*, 8(2), p. 45

“马” (as shown on the right side), mǎ (/ma/3), as another simple character, means horse. An example of a compound character is “妈”, mā (/ma/1), means mother. As McBride-Chang et al. (2005) explain that “in compound Chinese characters, there is a phonetic component, which sometimes gives a clue to the sound of the character, and a semantic radical, which sometimes gives a clue to the character’s meaning” (p.101). The Chinese language features a distinct writing system in which Chinese characters are intricately linked with morphemes, and frequently convey meaning through visual configurations.

Figure 1.3

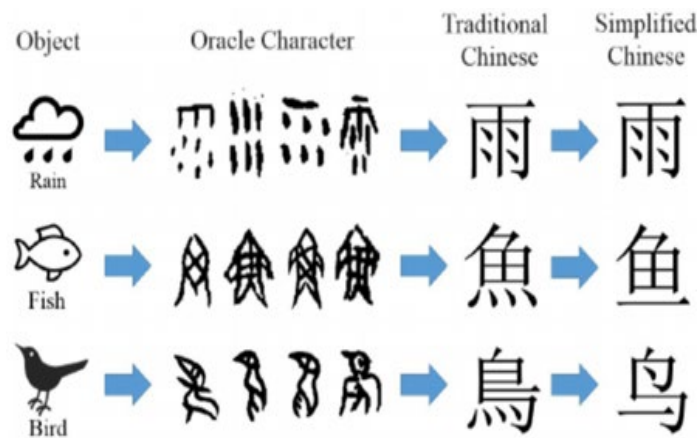
Example of Chinese orthographic system



As mentioned previously, the Chinese writing system consists of two different scripts: simplified script and traditional script (as shown in Figure 1.4), which are used in different regions. For most L2 Chinese learners, opting for the simplified script is a common choice, since “compared to traditional characters, simplified characters have approximately 22.5% fewer strokes” (Gao & Kao, 2002; as cited in McBride-Chang et al., 2005, p.107). However, there are exceptions for learners studying L2 Chinese in regions where traditional Chinese script is the norm.

Figure 1.4

Example of Chinese characters in the simplified and traditional script³



The aforementioned unique characteristics of the Chinese writing system highlight a stark contrast between English and Chinese, two of the world's most widely used languages. The situation becomes more complex when individuals are learning languages that lack substantial similarities to their first language (L1). Concerning Chinese L2 reading, Tan et al. (2003) conclude that “the cortical organization of phonological knowledge of written words reflects associations with visual features and associations with linguistic attributes” (p.164). In such cases, the learning process of Chinese as L2 can indeed be more demanding and challenging.

The Learning Characteristics of Thai Learners

The aim of this study is to explore the relationship between WM and L2 reading comprehension. It is hoped that this will yield insights that can lead to potential solutions and strategies for providing pedagogical support to Thai students learning Chinese as a foreign language. With this in mind, it is helpful to briefly consider key features of the Thai language as well as the circumstances of Thai students learning Chinese in an English-medium context.

³ Note: Adapted from “Building hierarchical representations for oracle character and sketch recognition,” by Guo et al., 2015, *IEEE Transactions on Image Processing*, 25, p.105.

In terms of the Thai language, similar to Chinese, the Thai language is also characterized as a tonal language. Unlike the Chinese but akin to English, the written Thai language uses the phonemic alphabet, ensuring that all syllables must contain a vowel sound while possibly starting and/or ending with a consonant sound. However, the pronunciation of a word is independent of its meaning. Both Thai and Chinese consist primarily of monosyllabic words, use similar word and sentence construction patterns, and do not conjugate either the verbs or nouns.

The process of Chinese language acquisition among Thai students in English-medium international schools could be more accurately described as third language acquisition(L3A). Ranong and Leung (2009) highlight that “the picture is more complex in L3 than in L2 because of the involvement of at least two or more previously learned languages” (p.163). The term L3A refers to the language that is currently being acquired, yet relatively little research has been conducted on WM concerning L3A. Furthermore, Hammarberg (2001) suggests that “the notion of SLA can also be understood in a wider sense where ‘second’ may refer to any language that the learner has added after infancy” (p.21). Thus, in this study, the notion of Chinese as L2 for Thai students learning in English medium international schools will be used for research purposes.

Research Questions

To unveil if WM is one of the critical factors in L2 reading comprehension, the main research question proposed for this qualitative study is: What is the relationship between WM and L2 reading comprehension?

This systematic review of literature attempts to identify, analyze, and appraise existing outcome measures in the evaluation of relationships between WM and L2 reading comprehension. Gaps have been identified at the initial stage of the research study. First, little

is known about the role of WM in reading comprehension across L2 language proficiency levels. Second, little is known about what role individual subcomponents of WM play in L2 reading, for example, how visuospatial sketchpad affects the processing of L2 learning. Finally, there is inadequate research using Chinese as L2. In the quest for relevant literature, many studies regarding the effect of WM and L2 have been done in languages that are characterized by alphabetic writing systems, but limited research has been done concerning the acquisition of the non-alphabetic writing system. This meta-synthesis study aims to address these gaps in the literature by focusing on the intriguing question of how WM affects L2 reading, particularly in the context of a phonologically opaque language like Chinese as an L2.

While focusing on the main research question, two other sub-questions will be examined during the investigation of the main research question.

Research Sub-Question 1: How does WM impact L2 reading comprehension across proficiency levels?

Research Sub-Question 2: What impact does the visuospatial sketchpad have on Mandarin L2 reading comprehension?

I argue that WM affects L2 reading comprehension across different proficiency levels and that the visuospatial sketchpad has a positive impact on Chinese L2 reading comprehension. Furthermore, I indicate that the results of this investigation offer helpful insights for pedagogical applications and propose some strategies for supporting Thai learners of Chinese as an L2.

Theoretical Framework

This literature review will examine the association between WM and L2 reading comprehension from a constructivist perspective. Honebein (1996) describes the

constructivist philosophical paradigm as an approach that asserts individuals' active construction of their understanding and knowledge of the world through firsthand experiences and subsequent reflection. Similarly, it is believed that "reality is socially constructed by people active in the research process and that researchers should attempt to understand the complex world of lived experience from the point of view of those who live in" (Schwandt, 2000, as cited in Mertens, 2019, p.49).

The objective of this study is to investigate the association between WM and L2 reading comprehension. This study employs a qualitative methodology, conducted as a systematic review of the literature within specific search parameters. It entails the collection of research results from various peer-reviewed articles published in recent years and synthesizes the research findings to advance our standing within this field of knowledge. The findings of this research study aim to identify possible valuable perspectives and lead to more effective teaching and learning strategies tailored to the needs and backgrounds of individual learners.

Overview of Research Methodology

Research Design

This study adopts a meta-synthesis research design to systematically analyze and synthesize existing empirical research aiming to investigate the relationship between WM and L2 reading comprehension. By synthesizing findings from a range of studies, the primary objective of this study is to provide a comprehensive review of the relationship between WM and L2 reading comprehension. Meanwhile, this study also serves the purpose of generating valuable insights and identifying patterns and potential knowledge gaps within this specific research domain for future research endeavors and pedagogical practice in this area.

Samples

For this study, a wide array of samples was rigorously selected based on predefined criteria to ensure their relevance to the research objectives. In this chapter, the criteria are briefly described as follows:

1. Peer-reviewed studies from 2004 onward, focused on L2 learners without disabilities.
2. Investigating the relationship between WM and L2 reading comprehension, using Baddeley's (2000) model.
3. Including measures for WM and L2 reading comprehension, and identifying proficiency levels among learners (e.g., beginner, intermediate, advanced).

The literature used for this study encompasses an extensive search of previously published peer-reviewed articles across multiple databases, with a focus on specific research topics of this study, such as WM, L2, reading, and related terms. To conduct the literature search for this study, keywords, and their combinations were used in various academic databases, mainly including Google Scholar search engine and Trinity Western University's Library OneSearch engine to increase the specificity of the search. Additional studies were found by manually examining reference lists within included studies to enhance the literature review's depth and breadth.

During the selection process, articles were screened based on the predefined selection criteria. The titles and abstracts of the articles were reviewed to identify potential matches with the research objectives. The articles that met the initial screening criteria then underwent a full-text review to assess their eligibility for inclusion in this study. The final selection of articles is based on the alignment of the research topics and the relevance of the findings.

Data Collection, Processing, and Analysis

During the data collection process, an organizer was used to summarize information from each selected study. The organizer served as a tool to gather and record important details from the literature, including the demographics of the participants, their L1 and L2 backgrounds, and other relevant information from each study. Furthermore, a matrix was also generated to identify and categorize key themes and patterns that emerged from the selected studies. These key themes and patterns served as a foundation as this study proceeds with the investigation and analysis of the relationship between WM and L2 reading comprehension, enabling the researcher to draw a meaningful conclusion.

Trustworthiness, Validity, and Reliability

The research approach of the study prioritizes trustworthiness, validity, and reliability to assure the robustness and credibility of its findings.

This meta-synthesis study adopts the constructivist paradigm, which encourages researchers to “obtain multiple perspectives that yield better interpretations of meanings” (Mertens, 2019, p.53) through document reviews. Therefore, the literature review draws upon peer-reviewed articles obtained from multiple reputable databases. Google Scholar, with its extensive coverage across diverse disciplines, serves as a primary search engine, especially when filtered by peer-review status. The Library OneSearch of Trinity Western University is used for supplemental research, capitalizing on its broader subscription access to updated publications available on platforms such as ResearchGate, Elsevier, and ScienceDirect. Notably, Elsevier journals, recognized for their high journal impact factor, contribute significantly to the overall exploration of the research topic. Additionally, the Education Resources Information Center (ERIC) is a valuable resource, hosting specific scholarly literature in the field of education. The references for this study include a broad range of

research methodologies, including qualitative research, quantitative research, meta-analysis, and meta-synthesis. These references have been selected and screened systematically, guided by predefined inclusion and exclusion criteria, ensuring the trustworthiness and validity of the data selection.

The outcome of the study is presented as a synthesis of research findings from different countries, reflecting a wide selection of L1 and L2 backgrounds. In the interpretation of these findings, the study maintains a rigorous approach, considering the trustworthiness, validity, and reliability of the included studies. Limitations identified in the original studies are explicitly addressed and incorporated into the study's overall interpretation.

While this research primarily benefits students studying Chinese as L2 in English medium international schools in Thailand, its implications extend beyond this context. The results hold relevance for Chinese as L2 learners in other English medium international schools across Asia, offering valuable insights to a wider educational landscape in the region.

Possible Limitations

Limitations of the study can always affect the interpretation and generalizability of the study. In this study, different limitations have emerged while the research was progressing. First is the language bias. Given that English is the predominant L2 studied worldwide, research involving L2 languages other than English, especially Chinese as an L2, is relatively scarce. Additionally, this literature review includes a broad age spectrum, ranging from kindergarten to adulthood. Nevertheless, the primary focus of this study is on adolescents in grades 9-12. It is worth noting that the age range within the included studies is somewhat limited, hindering a comprehensive understanding. Finally, it is important to note that the findings of this research are exclusively derived from the studies included in this

investigation and do not encompass other potentially impactful studies within the research area.

Despite these limitations, this meta-synthesis study serves a valuable purpose by raising awareness of the cognitive linguistic aspects of language learning. It offers insights that can be beneficial to L2 educators who teach students from diverse language backgrounds, helping them better understand the role of WM in the L2 learning process.

Ethical Consideration

According to Mertens (2019), “ethics in research should be an integral part of the research planning and implementation process” (p.45). As the researcher of this literature review study, I adhere to the ethical guidelines when using published peer-reviewed articles, considering the findings' ethical implications to remain unbiased. All the cited sources are acknowledged to avoid plagiarism. As this study is conducted representing a cross-cultural context, it maintains sensitivity to cultural and social differences and has also ensured the study proceeded in a fair and equitable manner without bias against such as race, gender, ethnicity, and nationality.

Conclusion

In conclusion, this chapter is presented as the introduction to the entire study. In this chapter, the problem statement has been explained to indicate the intention of this research. The definitions of the terms are also explained to better understand the contemporary development of theories in WM and L2 learning. Research questions have been raised to anchor the main research direction in this study. Lastly, other essential components that assist this study have also been highlighted, such as the theoretical framework, the overview of the research methodology, trustworthiness, validity, reliability, possible limitations, as well as ethical considerations.

In Chapter Two, a comprehensive overview of the methodology is explicitly presented. Chapter Three delves into the reviewed literature, offering a qualitative meta-synthesis that explores the relationship between WM and L2 reading comprehension. Chapter Four consolidates the key findings from this research, anticipating future investigations and interventions, as well as discussing pedagogical implications for the inclusive classroom. The concluding chapter provides a summary of the study and establishes the groundwork for potential research directions.

Chapter Two: Methodology

This research is presented as a qualitative systematic review of the literature. This literature review aims to provide a comprehensive overview of previously published academic studies relevant to the research topic. The primary focus of this research centers on uncovering how WM and L2 reading comprehension are related. To achieve this goal, this literature review compiles and synthesizes research findings from selected peer-reviewed scholarly articles. It is designed to systematically discuss the current body of knowledge and also to identify the gaps in existing research. As McGregor (2018) notes, “a literature review builds a picture, or portrait, of prior knowledge that has accumulated around a topic, thereby bringing the author and readers up to date on the current state of knowledge” (p.280). Furthermore, to keep up with the accelerating forefront of the research in this field, conducting a qualitative systematic review of the literature has become imperative. This endeavor seeks to identify areas requiring further investigation, specifically in the context of supporting students with limited WM capacity in an inclusive Chinese L2 learning environment.

Research Design

The research design of this study lies within the constructivist paradigm, a framework that achieves recognition in both research and educational domains. As highlighted in the introduction chapter, the constructivist paradigm posits that “knowledge is socially constructed by people active in the research process and that researchers should attempt to understand the complex world of lived experience from the point of view of those who live it” (Schwandt, 2000, as cited in Mertens, 2019, p.49). This perspective emphasizes that “reality is socially constructed” (Mertens, 2019, p.51), which means learners are not merely passive recipient of information, rather, they actively engage in the process of constructing

knowledge. Additionally, the constructivist paradigm encourages constructivist researchers to “obtain multiple perspectives that yield better interpretations of meanings” (Mertens, 2019, p.53) through document reviews.

In the field of research, over the years, Baddley’s developmental investigations into the mechanics of WM have demonstrated the conceptual links between how individuals actively employ their WM capacity in both cognitive and educational contexts for processing information. Beginning with Baddley and Hitch’s (1974) seminal suggestion that “WM plays a part in verbal reasoning and in prose comprehension” (p.86), Baddley’s (1992) subsequent work continues to “link WM to performance on a range of important tasks, including language comprehension and reasoning” (p.559). His emphasis on recognizing the variability in cognitive abilities across individuals has been instrumental. In Cowan’s (2022) observation, he points out the development of WM, stating that “constructivism increases the amount of attention paid to the possibility that storage is flexible and regulated strategically by the individual, as opposed to an inflexible and rote storage mechanism” (p.16). This perspective promotes a learning environment that aligns with the constructivist paradigm, supporting individuals in actively constructing their own understanding and utilizing their WM effectively. Baddley (2015) particularly note that “the multi-component model of WM was developed with the dual aims of providing a framework for the basic understanding of human memory, and at the same time providing a bridge to application beyond the laboratory” (p.17). In light of these insights, as Cowan (2022) concludes, “to understand behavior, their previous insights must be combined and must explain how knowledge and strategies are constructed” (p.17).

In the field of education, individual differences affect teaching and learning experiences. The implementation of philosophical paradigm can greatly enhance learning outcomes, fostering an environment conducive to achieving optimal teaching and learning

experiences. Amineh and Asl (2015) indicate that “in constructivism, learning is represented as a constructive process in which the learner is building an internal illustration of knowledge, a personal interpretation of experience” (2015, p.11). Bada and Olusegun (2015) also proclaim that “constructivist teaching is based on recent research about the human brain and what is known about how learning occurs” (p.69).

In this research study, to examine the relationship between WM and L2 reading comprehension, it is significant to advocate the necessity of an adapt constructivist paradigm as it “seeks to understand a phenomenon under study from the experiences or angles of the participants using different data collecting agents” (Adom et al., 2016, p.5). Researchers in the field of cognitive psychology and SLA have extensively researched WM and L2. Thus, it has become essential to reflect on the research findings and integrate them to gain a comprehensive understanding of the prevailing trends and patterns in this field. Meta-synthesis is one such means of achieving this goal.

The method of meta-synthesis is used in this literature review in an effort to provide valuable and significant insights within the realm of qualitative research. Qualitative meta-synthesis incorporates the aggregation of qualitative data from a variety of studies, interprets the findings, and synthesizes a novel theory within the research domain. Mohammed, et al. (2016) acknowledge that “evidence from the synthesis of qualitative studies can provide in-depth insight into a studied phenomenon” (p.695). The overarching objective of this meta-synthesis is to examine recent literature pertaining to the interplay between WM and L2 reading comprehension, summarize the findings, and use these theories as a basis to provide practical guidance to educators on how to effectively instruct and support learners with limited WM capacity in an inclusive Chinese L2 classroom.

Samples

This literature review draws from samples sourced across a range of electronic databases, ensuring a comprehensive exploration of relevant sources. The databases include the Google Scholar search engine, Library OneSearch of Trinity Western University, SAGE journals, JSTOR, the WILEY online library, Academia, Elsevier, the Education Resources Information Center (ERIC), ResearchGate, and ScienceDirect. To further enrich the pool of potential sources, additional studies were identified through a manual examination of the reference lists within the included studies, enhancing the depth and breadth of the literature review.

The search adopts many variations and combinations of the following keywords in this research: *executive functions, working memory, working memory capacity, second language, foreign language, reading comprehension, reading span, visuospatial, proficiency level, Mandarin, Chinese, etc.* This multifaceted approach ensures a thorough exploration of the relevant literature, encompassing a wide spectrum of terms and concepts associated with the research topic.

The meta-synthesis process rigorously adhered to a set of well-defined selection criteria to ensure the inclusion of diverse and relevant studies that meet the research questions while upholding methodological rigor and clarity. The works of literature that have been collected for this study are within the search parameters, including both qualitative research and quantitative research. To be included in this literature review, each study had to meet the following criteria:

1. The study must be published in peer-reviewed journals and provide sufficient information regarding its study design, participants, measures, and results.
2. The study should have been conducted and published in the year 2004 or later, ensuring the incorporation of recent research findings.

3. The study must involve participants as L2 learners who do not have learning disabilities or language impairments, thereby focusing on a specific subset of the population.
4. The study should investigate the relationship between WM and L2 reading comprehension and report a relationship. This entails that:
 - a. The study should adopt the model of WM proposed by Baddeley (2000) as its theoretical framework.
 - b. The study should have administered at least one measure of WM and one measure of L2 reading comprehension.
 - c. The majority of the studies should identify the proficiency levels of the L2 learners, such as beginner, intermediate, or advanced learners, to add depth to the analysis.

Through this selection process, the database searches yielded a total of 22 journal articles that met these rigorous selection criteria. This meta-synthesis comprises a comprehensive examination of 22 studies that investigated the relationship between WM and L2 reading. These studies involved a diverse range of participants, hailing from various L1 backgrounds, such as French, English, Portuguese, Chinese, Turkish, Korean, Thai, Spanish, German, Russian, Cantonese, Persian, and Japanese. Contrastingly, the L2 being examined in these studies exclusively focused on English as a major L2 target language, although a few studies also considered Spanish, Chinese (Mandarin), and Japanese as secondary L2 languages. The participants included in this meta-synthesis were drawn from various sources, culminating in a total of 1,615 participants. Their ages span a wide range, from as young as 4 years old to as mature as 35 years old.

The majority of the participants are university students learning English as L2. These participants are learners of L2 at multiple proficiency levels. The L2 proficiency levels are in

three main categories: beginning, intermediate, and advanced. Among 1,615 participants, 299 participants are at the beginning levels, 674 participants are at the intermediate levels, 494 participants are at the advanced levels, and 148 participants' levels are unspecified. For a more in-depth exploration of the characteristics and experiences of these participants, the following Table 1 provides additional details.

Organization and Analysis of Data

The organization and analysis of data for this study, exploring the relationship between WM and L2 reading comprehension, involves an in-depth examination of how these two variables are related.

During the initial stage of gathering and selecting relevant articles to study, the main focuses were widely spread to different multifaceted factors that will have an impact on the relationship between WM and L2 reading comprehension, such as the development of the models of WM, the role of WM in reading both in L1 and L2, the design of reading span tasks, the relationship between SLA and WM capacity, and the implementation and efficiency of WM training.

Building upon the foundational theories from the initial stage of research, the subsequent phase of information collection integrated specific selection criteria to identify studies closely aligned with the research objectives. The titles and abstracts of the articles were reviewed to identify potential matches with the study's goal. Around 30 studies were identified as promising candidates for further investigation. These selected articles then underwent a full-text review to assess their eligibility for inclusion in this study. Among them, 22 articles were ultimately chosen to advance into the literature review phase.

Table 1. All studies included in the meta-synthesis

Study	Age Group	Number of Participants	L1	L2	L2 Proficiency level(s)
Walter, C. (2004)	13-19	41	French	English	Intermediate
Leeser, M. J. (2007)	>18	94	English	Spanish	Beginning
Fontanini and Tomitch (2009)	18-22	42	Portuguese/Chinese	English	Intermediate
Alptekin and Erçetin (2009)	20-23	30	Turkish	English	Intermediate
Kim, S. A. (2010)	18-27	70	English/Korean/etc.	Chinese	Beginning/Intermediate
Alptekin and Erçetin (2010)	20-23	43	Turkish	English	Advanced
Alptekin and Erçetin (2011)	20-23	62	Turkish	English	Advanced
Chung and McBride-Chang (2011)	4-5	85	Chinese	English	NA
Choi, S. (2013)	20-24	46	Korean	English	Advanced
Bailer et al. (2013)	14-17	61	Portuguese	English	Intermediate
Tsai, A. M. (2014)	18-32	30	English	Japanese	Intermediate
Shahnazari-Dorcheh & Adams (2014)	19 (Mean age)	55	Persian	English	Beginning/Intermediate/Advanced
Shibasaki et al. (2015)	15-17	120	Japanese	English	Intermediate
Kim et al. (2015)	18-27	70	English/Korean/etc.	Chinese	Beginning/Intermediate
Kim et al. (2016)	18-27	70	English/Korean/etc.	Chinese	Beginning/Intermediate
Joh, J., & Plakans, L. (2017)	21 (Mean age)	80	Korean	English	Intermediate/Advanced
Jung, J. (2018)	22.84 (Mean age)	52	Korean	English	Intermediate
Chang et al. (2019)	12-14	230	Chinese	English	Intermediate
Shin et al. (2019)	18-26	79	Korean	English	Intermediate
Huang et al. (2022)	17-20	52	Chinese	English	Intermediate
Pretorius et al. (2022)	8-9	63	Afrikaans	English	NA
Shahnazari, M. (2023)	16-35	140	Persian	English	Beginning/Intermediate/Advanced
		Total: 1615			

These 22 articles were then examined for cohesive themes and patterns. Following an extensive review of 22 journal articles, during the data extraction phase, the information and data collected from each study were synthesized to identify common themes and patterns across the studies. To aid in visualizing these recurring themes and patterns from the literature, a matrix (see Appendix A) was generated. These themes and patterns have been color-coded and categorized in alignment with their relevance to the research questions. This following Table 2 is a brief summary of Appendix A.

Table 2. Cohesive Themes and Patterns

Themes and Patterns	Research Areas of WM in L2 Reading	Number of Studies
WM Components	Central Executive	3
	Phonological Component	10
	Visuospatial Component	3
	Episode Buffer	0
L2 Processing	L2 Word Recognition and Vocabulary Acquisition	9
	L2 Sentence Processing	3
	WM Capacity and L2 Reading Comprehension	7
	Task Demands	7
Individual Variability	Age Group	2
	L2 Proficiency Level	5
	L1 Prior Knowledge	6
Others	Interventions	2

However, it is noteworthy that only five studies within the selected pool employ ideographic language as L2, and among these, merely three studies specifically researched the role of the visuospatial sketchpad in L2 reading. Given the emphasis on Chinese as the

target L2 in this study, it becomes imperative to include research involving ideographic language as L2 to comprehensively investigate the influence of the visuospatial sketchpad.

After the examination, three key themes and patterns have surfaced, directing our inquiry into the relationship between WM and L2 reading comprehension. These themes are the impact of various WM components, WM and L2 processing, and the impact of individual differences. The first theme, which scrutinizes the diverse effects of distinct WM components, provides insights into the key research question and the second sub-research question, elucidating the influence of the various WM components, including visuospatial sketchpad, on Chinese as an L2 reading comprehension. The second theme continues to link to the key research question, which explores how WM impacts L2 processing, focusing on reading comprehension. The discussion of the last theme is instrumental in addressing the initial sub-research question, probing how learners' WM affects L2 reading comprehension across proficiency levels. Beyond these core themes, the discussion will also extend to intervention design aimed at providing support to students with limited WM capacity within the inclusive educational setting. This expanded perspective will yield valuable implications for the development of future instructional strategies.

Conclusion

This chapter has furnished an explicit overview of the methodology employed in the investigation of the relationship between WM and L2 reading comprehension. This methodological exposition serves as a sturdy foundation and framework, facilitating the progression towards achieving the objectives of this study. The upcoming chapter will dive deeper into the reviewed literature, building upon the groundwork established in this chapter.

Chapter Three: Literature Review

The literature review in this chapter is geared toward addressing the research questions that have been posed about WM in this qualitative study: How does WM impact L2 reading comprehension with its two sub-questions: How does WM impact L2 reading comprehension across proficiency levels and What impact does the visuospatial sketchpad have on Mandarin Chinese as L2 reading comprehension? These inquiries collectively form the crux of the investigation, aiming to shed light on the intricate relationship between WM and L2 reading comprehension, with a specific focus on the unique dynamics within a Chinese as L2 learning context.

The chapter that follows is organized into three sections, namely the effects of distinct WM components, WM and L2 processing, and the impact of individual variability. Within these three main topics, there are eleven subtopics to be discussed as displayed in Table 2.

Effects of Distinct WM Components

Central Executive

As one of the WM components, the central executive is the control center of WM, regulating and coordinating cognitive processes, such as attentional control, planning, reasoning, and problem-solving. In the context of L2 reading, the central executive allocates attention to various aspects of readings, such as decoding unfamiliar words, understanding complex sentence structures, and grasping the overall meaning of the text. Baddeley (2012) notes that “the central executive is a purely attentional system with no storage capacity” (p.14) and the “key function of the central executive is the allocation of attentional resources” (Barrett, Tugade, & Engle, 2004, as cited in Arrington et al., 2014, p.326). The central executive not only helps L2 learners focus on the relevant linguistic features but also directs attention to the contextual meaning at the same time.

The significant role of the central executive in L2 reading comprehension has been extensively studied. Chung and McBride-Chang (2011) highlight the significance of attentional control, specifically the ability to suppress irrelevant information while engaging in the rapid search and recall of relevant information. Li and Clariana (2018) explain that L2 learners “with greater WM capacity could allocate the needed attention better while performing the linguistic task, which may explain the influence of WM on reading comprehension” (Chang et al. 2019, p.467). Huang et al. (2022) recently proclaim that L2 learners with higher WM capacity are advantaged in processing unfamiliar words as they can efficiently direct their attentional resources to unfamiliar words when they first fixate on these target items. In accordance with Bailer et al. (2013), “higher spans have more ability to sustain attention to form simultaneously to meaning” (p.145). These insights suggest that L2 learners with a strong central executive function are well-equipped to manage the complexities of reading in L2. However, in situations where L2 learners find themselves “overwhelmed by the complexity of L2 input, their attention serves to bring order to the chaos by sorting out that input, sometimes succeeding in helping and, at other times, overwhelming the learner” (Bailer et al., 2013, p.140). This implies the interplay between the central executive and L2 is dynamic, sometimes functioning as a valuable resource for L2 learners and sometimes posing challenges by amplifying the cognitive load.

To sum up, the central executive’s significance in L2 reading is evident through extensive research. L2 learners with greater WM capacity excel in allocating attention for enhanced reading comprehension. However, the interplay between the central executive and L2 input is dynamic, which highlights the complexity of L2 reading comprehension.

Phonological Loop

Another WM component, the phonological loop, comprises a phonological store, and it stores and processes the auditory information. The role of the phonological loop has been identified as a key factor affecting reading comprehension, in both L1 and L2 contexts.

As a short-term storage center, the phonological loop WM allows people to retain, rehearse, or practice verbal information to facilitate recall later on. Reading comprehension requires active decoding, where words are dissected and matched with their corresponding letter-sound combination. As a sub-component of WM, phonological loop WM actively maintains the deconstructed word for a sufficient period of time, allowing the word's meaning to be extracted from semantic LTM. This process ultimately contributes to a comprehensive understanding of the text being read.

During this literature review, several studies (Walter, 2004; Kim, 2010; Chung & McBride-Chang, 2011; Tsai, 2014; Shahnazari-Dorcheh & Adams, 2014; Baddeley, 2015; Kim et al., 2015; Kim et al., 2016; Jung, 2018; Chang et al., 2019; Pretorius et al., 2022) have investigated the relationship between the phonological loop component of WM and reading comprehension, yet they have yielded inconsistent results in different research. Baddeley (2015) confirms the effects of the phonological loop component of WM are evident in L1 learning and L2 learning. In the context of L2 reading, Jung (2018) emphasizes the positive contribution of phonological WM to L2 reading comprehension, stating that “a larger phonological short-term memory span allowed the participants to retain more textual information, facilitating more efficient handling of mixed paragraph order” (p.31). In contrast, Shahnazari-Dorcheh and Adams (2014) report that no direct relationship between phonological short-term memory and reading measures. Instead, they suggest that the impact of phonological short-term memory is primarily confined to vocabulary acquisition in both L1 and L2 learning, ultimately influencing reading comprehension.

The concept of the phonological loop and its role in WM is primarily associated with alphabetical language, where words are composed of phonemes that correspond to letters or letter combinations. However, logographic language learning, such as Chinese or Japanese, which do not rely on phonemic decoding as in alphabetical languages, has been reported to relate to phonological loop (Kim, 2010; Tsai, 2014; Kim et al., 2015). Kim (2010) in an experiment detects both the phonetic stage and the orthographic stage for adult Chinese L2 learners, and it is explained as follows:

When participants were forced to read unknown phonetic compound characters containing the same phonetic as the learned characters, most participants succeeded in reading novel compound characters by utilizing the phonetics of characters they had learned, and their reading thereby achieved more than 87% accuracy in reading new characters. (p.75)

Kim et al. (2015) provide evidence that supports the utilization of both phonetic and orthographic strategies while reading novel Chinese characters. To effectively employ these strategies, a strong knowledge of a certain number of regular and conventional Chinese characters is essential. Additionally, the role of the phonological loop in character reading is evident. In situations where compound Chinese characters contain phonetic consistencies with familiar semantic radicals, Chinese L2 learners are more likely to succeed in reading the new characters and comprehending these new characters.

Chinese, characterized as a phonologically opaque language, has increasingly drawn the attention of researchers investigating the impact of the phonological loop in the context of Chinese L2 learning. Regarding the inconsistencies of the effects of the phonological loop component of WM in different studies, Pretorius et al. (2022) especially highlight that “achieving clarity on this matter can potentially be beneficial to detecting and intervening L1 and L2 learners with reading comprehension difficulties” (p.1). By understanding the role of

the phonological loop in Chinese L2 learning, educators and researchers can better address the specific needs of L2 learners and enhance their reading comprehension skills.

Visuospatial Sketchpad

As its name implies, the visuospatial sketchpad takes charge of visual images and spatial relations. The visuospatial sketchpad is one of the vital factors for retaining visual representations of letters or characters and their spatial arrangement in memory.

In this study, one of the research sub-questions aims to investigate how the visuospatial sketchpad is involved in processing the visual aspects of logographic characters, including Chinese characters, and its broader implication for Chinese L2 reading comprehension. Therefore, it is hypothesized that the visuospatial sketchpad is crucial for Chinese L2 learning. Specifically, it aids in visually encoding the sequence and spatial arrangement of strokes within each Chinese character, associating characters with their respective meanings, and eventually contributing to overall comprehension of the context.

As mentioned earlier, phonological loop WM has been regarded as a strong predictor of L2 reading development in the area of learning new vocabulary, reading comprehension, and overall L2 proficiency in alphabetic languages such as English. Whereas, Pham and Hasson (2014) expose that “because of the emphasis placed on verbal WM in the literature, there has been limited research on the role of visuospatial WM as it pertains to higher-level reading skills, particularly reading fluency and comprehension” (p.468). Moreover, studies that probe the relationship between WM and L2 learning have primarily emphasized alphabetic languages as L2 research languages, such as English as L2. Alphabetic languages correspond between the written form and the pronunciation of words, making learning and reading easier for learners whose L1 is a similar alphabetic language as English.

Taking into account its visual complexity and phonological opacity, the Chinese writing system is an ideal candidate for examining the role of both phonological loop WM

and visuospatial sketchpad WM in L2 learning. In this literature review, among all the twenty-two studies, four studies (Kim, 2010; Tsai, 2014; Kim et al., 2015; Kim et al., 2016) adopt logographic languages as L2 research languages, including Chinese or Japanese, and among these four studies, three studies use Chinese as L2 research language. These four studies are noteworthy as they specifically delve into the impact of visuospatial sketchpad in WM when apply to logographic language as part of the L2 learning investigation.

In Kim's (2010) study, she did not detect the evidence for the visual stage in adult L2 reading acquisition. This finding diverges from the reading strategies adopted by child L1 Chinese learners, who rely on visually distinctive features to read characters. Kim's (2010) study indicates that adult L2 Chinese learners progress through a different trajectory. Initially, they enter a phonetic stage when learning to read characters, and subsequently proceed to the orthographic stage, wherein they make use of consistent Chinese character systematic rules, especially as their character knowledge expands. However, it is worth noting here that the human brain undergoes significant changes and development throughout the lifespan, the cognitive processing of adults differs from that of children or young adults because of the maturation of the brain.

Kim (2010) also extends beyond Chinese and touches upon the existence of a visual stage in languages other than Chinese, such as English. In her study, Kim (2010) discloses that "L1 Chinese learners may stay in the visual stage longer than L1 English learners" (p.14). Children whose L1 is an alphabetical language with a shallow orthographic system seem to initially rely on visual features before transitioning to the alphabetic strategy. Whereas, L1 Chinese child learners, who start by depending on the visually distinctive features of Chinese characters, tend to begin in the visual stage and continue this reliance as they attain more character knowledge.

Kim et al. (2015) investigate how the distinctive visual features of Chinese characters interact with WM, and they find that “L2 learners relied more heavily on visuospatial WM while processing characters with atypical, exaggerated strokes, and on verbal WM when processing regular and conventional Chinese characters” (p.22). While investigating orthographic consistency and individual learner differences in Chinese as L2 learning, Kim et al. (2016) once again supported the reliance on visuospatial WM at the initial stage of learning Chinese characters. As the L2 learners progress and accumulate more knowledge, the influence of visuospatial WM on character learning starts to diminish. Instead, other factors such as L2 proficiency and consistent knowledge of L2, contribute to learning characters that share phonetic information. This highlights the evolving role of WM in the language acquisition process.

On the contrary, while researching the relationship between visuospatial WM and Japanese L2 reading proficiency, Tsai (2014), in her study prove that “there are no correlations were found between visuospatial WM task and Japanese reading proficiency” (p.101). However, aligning with the research results from Kim (2010) and Kim et al. (2015), Tsai’s (2014) study reveals a correlation between verbal WM tasks and Japanese reading proficiency.

When considering L1 Thai learners, it is noticeable that the Thai language features a distinct writing system that sets it apart from the alphabetic language system. The Thai language uses an abugida writing system, characterized by combining consonants and vowels into a single unit, with each unit representing a syllable rather than an individual sound or phoneme. This distinctive feature of Thai writing shares similarities with Chinese, as both languages contain orthographic features and engage the visuospatial sketchpad during reading and other cognitive language-related tasks for their respective L1 learners. Kim et al. (2015) identify that “L1 Chinese readers tend to use visual strategies longer in the beginning

stage of literacy and have better visual skills than native readers of alphabetic writing systems, ostensibly due to the Chinese readers' experience with visually complex characters” (p.10). Therefore, it is reasonable to infer that early-stage literacy development of Thai L1 learners may involve a reliance on visual strategies as well.

In an inclusive classroom, it is possible that students with limited WM capacity use visuospatial WM as a compensatory mechanism, as Pham and Hasson (2014) mention that “children with reading difficulties may likely rely on visuospatial WM or imagery as a strategy to process written text and comprehension” (p.476). In the matter of languages using alphabetical letters, this phenomenon can be attributed to the challenges they encounter in phonological processing. The reliance on visuospatial strategies will help L2 learners form a mental association to help them understand and remember the context, by bypassing difficulties they experience with phonological processing, though affects reading fluency and comprehension as effectively as skilled readers. With regard to processing logographic languages such as Chinese characters, learners experience challenges with phonological aspects and tend to prioritize visuospatial processing.

A holistic approach addressing both the visual and phonological aspects of Chinese character processing is essential. As Kim et al. (2015) address that “learning ordinary Chinese characters is essentially a linguistic task for L2 character learners” (p.21), which implies that once learners have learned basic simple characters and developed an awareness of how phonetic rules apply to character knowledge, phonological aspects of character processing will play a more prominent role in L2 Chinese character learning.

While researching this topic, it is worth noting here that the effect of visuospatial sketchpad WM has not received wide attention from SLA researchers. It is a delight to witness research discussing the role of visuospatial sketchpad WM has arisen on both L1 and

L2 reading and writing processes, especially targeting the relation between visuospatial WM and reading proficiency in logographic languages.

Episodic Buffer

The newest component of the WM model, the episodic buffer, is a link from WM to long-term memory, and it was added by Baddeley in 2000. The episodic buffer WM has not received as much attention from SLA researchers compared to other components of WM, therefore the episodic buffer component has not been extensively incorporated into the existing body of literature in this field.

WM and L2 Processing

WM holds significant importance in the processing of L2, and each component works together to support various aspects of L2 processing. When WM in L2 learning has been recognized as important as it is in L1 learning, there is a surge of research to explore the relationship between WM and L2 learning. According to a recent study, Li (2023) maintains the belief that “WM is a significant predictor for various aspects of L2 learning” (p.357).

The effect of WM is vital in various aspects of L2 processing, including word recognition, vocabulary acquisition, sentence comprehension, and the management of task demands, etc. Each of these individual aspects, along with their synergistic interaction, significantly influences the overall achievement of L2 processing.

WM and L2 Word Recognition and Vocabulary Acquisition

Both L2 word recognition and L2 vocabulary development are essential components contributing to proficient L2 reading. The ability to decode words and grasp the meanings of these words is the cornerstone of skillful reading comprehension. Within this context, WM emerges as a crucial determinant in L2 word recognition and vocabulary acquisition. When

encountering unfamiliar words, L2 learners must allocate their cognitive resources to process and assimilate a blend of phonological, orthographic, and semantic information associated with these words. WM helps with the temporary storage of the information, thereby, enabling L2 learners to effectively link it to their pre-existing knowledge. This facilitates the retrieval of the word-related knowledge during the recognition and acquisition process, ultimately contributing to the consolidating of this knowledge into LTM.

In this literature review, multiple studies (Leeser, 2007; Kim, 2010; Chung & McBride-Chang, 2011; Choi, 2013; Bailer et al., 2013; Shibasaki et al. 2015; Kim et al., 2015; Kim et al., 2016; Huang et al., 2022) have researched the role of a learner's WM in the process of acquiring new words in a different language. Lesser (2007) summarizes the result from Chun and Payne (2004) and discloses that “no significant findings for WM on any of the comprehension or vocabulary acquisition measures” (p.237), yet Huang et al. (2022) recently proclaim that “during L2 reading the first fixation duration on unfamiliar words is associated with readers' WM capacity and L2 reading comprehension performance” (p.11). In addition, Wen and Li (2019) specify that “phonological WM has been generally found to be closely related to some acquisitional and developmental aspects of such mental representational domains as vocabulary learning, grammar learning, and development of L2 fluency” (p.380).

When considering Chinese as an L2 for word recognition and vocabulary acquisition, several unique factors come into play. Firstly, Chinese words are constructed using ideographic characters, requiring Chinese as L2 learners to simultaneously hold and manipulate both the visual and phonetic aspects of these characters. Secondly, the Chinese vocabulary is extensive, comprising a vast number of characters and words. Consequently, Chinese L2 learners must establish strong associations with LTM to retrieve and encode the meaning of these characters and words. Due to the complexity and visual nature of Chinese

characters, processing Chinese as L2 apparently expends additional cognitive demands and has the potential to overload WM capacities. In this context, Kim et al. (2015) observes that learners with higher levels of individual WM were better able to learn to read simple Chinese characters. This emphasizes the critical role of WM in coping with the intricacies of acquiring Chinese as L2, especially in the initial phases of character recognition and vocabulary acquisition.

With these findings in mind, it becomes evident that subcomponents of WM collectively affect the processes of word recognition and vocabulary acquisition, not only in the broader context of learning an L2 but also specifically in the case of acquiring Chinese as an L2.

WM and L2 Sentence Processing

A strong WM in L2 word recognition and vocabulary acquisition provides a solid foundation for L2 sentence processing. WM is inherently involved in L2 sentence processing (Juff, 2015; Zhou et al., 2017; Cunnings, 2022). When processing sentences in L2, L2 learners tend to process words and phrases and integrate grammatical information to facilitate sentence comprehension, meanwhile simultaneously maintaining and managing the various pieces of information until the intended meaning of the sentence is grasped. In contrast to the processing of sentences in L1, L2 learners often take additional time to process and identify those syntactic nuances that are typically automatic for them when dealing with L1 sentences in light of their extensive exposure to their L1. During this process, L2 learners have to integrate their vocabulary and grammar knowledge from their LTM to establish the syntactic and semantic relationship between words. WM assists learners in parsing the sentence into meaningful chunks, such as phrases and clauses. It coordinates the integration of words and grammar elements, serving as a temporary storage system for sentence components.

Research in this field has reached a consensus across various studies regarding the challenges posed by sentence processing for L2 learners with limited WM capacities. Fontanini and Tomitch (2009) highlight that “L2 reading can impose an additional burden on the reader, taking into account that different variables can affect the process” (p.2). Processing sentences in L2 is complex and challenging, particularly for learners with limited WM capabilities. Parsing and comprehending complex sentences rely heavily on WM capacity. L2 learners may encounter difficulties with sentence comprehension, slowing reading speed, or increased errors in understanding complex sentence structures. Not to mention long and intricate sentences, it will need a high demand for WM capacities. The limited retrieval of WM can result in incomplete or inaccurate comprehension of the sentences.

Cunnings (2017) stresses that “successful sentence and discourse comprehension crucially relies on the ability to encode, store, and retrieve information from memory” (p.42). Cunnings (2022) also demonstrates that “capacity-limited L2 readers have difficulty taking multiple sources of information into account during real-time sentence processing” (p.6). L2 learners with limited WM capacities, particularly within an inclusive language learning environment, may encounter difficulties in keeping track of all the relevant information. This challenge can lead to struggles in parsing the sentences into manageable chunks for more accessible processing, ultimately resulting in misunderstandings and misinterpretation of sentences and passages. These collective insights highlight the pivotal role of WM in L2 sentence processing and the significant hurdles faced by L2 learners with limited WM capabilities in effectively comprehending complex sentences and discourse.

WM Capacity and L2 Reading Comprehension

WM capacity is a valuable cognitive resource, and it contributes to overall L2 proficiency. “WM capacity is shown to correlate significantly with L2 reading

comprehension” (Walter, 2004; Leaser, 2007; as cited in Alptekin & Erçetin, 2010, p.207).

Reading comprehension is a complex cognitive process that contains multi-facets of constructing stages and links to several aspects. With various researchers proposing a variety of variables that affect L2 reading, WM capacity emerges as a prominent variable that should be carefully considered in the trajectory of L2 reading research.

Seigneuric and Ehrlich (2005) indicate that “WM, as one of the EF components, is a determinant of reading comprehension” (p. 619). This finding holds true for both L1 reading and L2 reading. Moreover, research on L1 reading contributes valuable insights to the understanding of L2 reading. Ever since Harrington and Sawyer (1992) pioneered the exploration of WM’s impact on L2 reading comprehension, a succession of seminal studies has continued to emerge, further illuminating the profound influence of WM on L2 Reading comprehension. Collectively, a body of research consistently affirms that WM capacity directly influences L2 Reading comprehension. Alptekin and Erçetin (2011) affirm the notion that “WM is central to L2 learning, not to mention its significant relationship with reading comprehension” (p.238). Linck et al. (2014) went a step further by demonstrating a positive association between WM and both L2 processing and proficiency outcomes, “with an estimated population effect size (ρ) of .255” (p.2). Recent work by Wen et al. (2020) once again reveals that “results have converged on the positive effects of WM on L2 learning processes and outcomes” (p.2). These cumulative insights underscore the significant role of WM capacity in L2 reading, impacting comprehension, processing, and proficiency in a positive and substantial manner. In other words, studies consistently imply that L2 learners with greater WM capacity tend to have better L2 reading comprehension skills.

As a complex cognitive operation, L2 reading consists of an integration of lower-level processing and higher-level processing. The lower-level processing in reading includes word recognition, lexico-syntactic processing, and semantic processing, providing the fundamental

groundwork for comprehending the text's surface-level meaning. On the other hand, higher-level reading is always associated with inference-making, schema-using, and prior knowledge to delve into deeper interpretations, establish connections, and engage critically with the reading content. The successful reading always involves the use of both lower-level processing and higher-level processing. The existing literature yielded mixed results regarding the effect of WM in both lower-level processing and high-level processing of L2 reading. Alptekin and Erçetin (2010) discover that "literal understanding did not correlate with any WM capacity measure" (p.214), yet "WM capacity plays an important role in reading comprehension, especially in those cognitively demanding reading tasks characterizing inferential reading" (p.215). This theory suggests that literal comprehension relies more on basic language processing skills, vocabulary recognition, and surface-level cognitive abilities, but as increased cognitive demands are involved, the effect of WM becomes more evident in tasks that go beyond basic literal comprehension. According to this viewpoint, as tasks increase in complexity, they will demand larger allocation of WM resources to be executed successfully. On the contrary, Shahnazari-Dorcheh and Adams (2014) provide compelling evidence for the effect of WM at the beginning level of L2 learning and they suggest that "L2 learners with low proficiency rely on WM more than high-proficiency L2 learners during reading tasks" (p.29). This reliance on WM is a common occurrence when language proficiency is limited and often results in an increased emphasis on lower-level processing during language-related tasks. In a recent study, Shahnazari (2023) further explain the reason for this reliance is caused by "the higher proportion of attentional resources being used in L2 reading processing at lower levels of proficiency" (p.12). In the context of Chinese characters reading, Kim et al. (2016) also disclose that WM is initially involved in learning basic characters, but as learners gain more L2 knowledge and exposure,

they can leverage phonetic consistency information and rely less on WM for basic processing tasks.

In summary, although previous research findings frequently observe a positive association between WM capacity and L2 reading comprehension, it is crucial to acknowledge that this relationship is not consistent across all contexts and individuals. Achieving a comprehensive understanding of its implication in the context of L2 reading demands a nuanced perspective that considers the multifaceted nature of language processing, individual differences among L2 learners, and the complex interactions between cognitive and linguistic factors.

Task Demands

The dynamic relationship between task demands and WM capacity is significant in L2 reading comprehension. Considerations like personal experience, prior knowledge, and cultural relevance highlight the importance of tailoring reading materials to optimize comprehension for L2 learners.

“Readability is a multifaceted construct involving both reader-specific and text-specific factors” (Castello, 2008; as cited in Alptekin & Erçetin, 2011, p.246). In the aspect of reader-specific factors, Leiser (2007) states that, “with regard to task demands, tasks based on familiar information could make noticing more likely because unfamiliar information might overload a limited processing capacity and render noticing of certain forms less likely” (p.231). Personal experiences and prior knowledge on the topic contribute to comprehension. Tailoring reading materials to match L2 learner's backgrounds and abilities can enhance comprehension outcomes. Alptekin and Erçetin (2011) recommend a strategy known as “the nativization of the context”, and this approach involves “the sociological, semantic, and pragmatic adaptation of the textual and contextual cues of the text into the reader’s own

culture-specific mental framework while keeping its linguistic and rhetorical content essentially intact” (p.246). This process ensures that the reading material is not only comprehensible linguistically but also culturally relevant and accessible to L2 learners, facilitating their overall understanding.

In the aspect of text-specific factors, the cognitive requirements and complexity of a task can impact the utilization of WM. When the task’s demands exceed the available capacity of WM, it can result in cognitive overload, leading to decreased performance. Likewise, if the task is complex and requires multiple steps to coordinate and process, individuals with limited WM capacity may encounter challenges in effectively managing and executing such complex tasks. Alptekin and Erçetin (2010) take into account two distinct dimensions of reading comprehension, namely, literal and inferential comprehension. Literal comprehension in reading involves the L2 learners directly retrieving information from the text to answer the questions. It serves as a fundamental building block for developing higher-level comprehension skills. On the other hand, inferential comprehension delves beyond the text’s literal or surface-level meaning, requiring the L2 learners to understand and interpret information not explicitly stated.

Several studies have explored the influence of WM on both literal and inferential comprehension. Alptekin and Erçetin (2010) consolidate findings suggesting that WM is a significant predictor of inferential comprehension, not literal comprehension, due to the superficial processing and lower cognitive demand of literal comprehension, whereas inferential comprehension requires heavier cognitive demand. Choi (2013) argues that “WM capacity and text-specific vocabulary were important for literal reading comprehension, while in inferential comprehension, text-specific vocabulary was the only significant predictor” (p.37), whereas Jung (2018) further proves the effect of WM in inferential comprehension, which is “when the text needs to be processed at a deeper level through careful reading for

successful task completion, the task seems to pose greater processing demands on L2 readers, calling for more attentive and accurate textual analysis” (p.22).

These findings highlight the complex interplay between WM and task demands in L2 reading comprehension. By taking into account task demands and customizing instructions accordingly, educators can establish a nurturing L2 learning environment for learners.

Impact of Individual Variability

Individual differences represent a significant factor influencing the impact of WM on L2 learning. Leiser (2007) summarizes that “comprehension is understood as an interactive process involving both input and individual variables” (p.231). Among a vast variety of factors affecting L2 learners’ learning experiences, individual differences are of great importance among all these variables. These individual variables consist of a broad spectrum, including age, aptitude, cognitive style, motivation, and more. This literature review will specifically focus on exploring the effects of age group, L2 proficiency level, and prior knowledge as critical individual differences in the context of L2 learning.

Age Group

Age is one of the primary factors that can shape SLA, with WM capacity undergoing dynamic developmental changes from childhood through adulthood. Young adolescents, at a developmental stage, depend on WM assistance for L2 reading comprehension. Childhood is marked by the advantage of rapid and natural language acquisition while adulthood brings cognitive benefits, including metacognitive skills and memory strategies. As L2 learners progress through different age groups, their WM capacity matures, enabling more efficient processing of L2.

This literature review includes L2 learners who are at different development stages. While age information is not specifically specified by Leiser (2007) and Fontanini and

Tomitch (2009), the remaining studies categorize participants into three age groups: young children, aged 4-5 (Chung & McBride-Chang, 2011); adolescents, aged 12-17 (Walter, 2004; Bailer et al., 2013; Shibasaki et al., 2015; Chang et al., 2019); and adults, aged 18-35 (Alptekin & Erçetin, 2009; Kim, 2010; Alptekin & Erçetin, 2010; Alptekin & Erçetin, 2011; Choi, 2013; Tsai, 2014; Shahnazari-Dorcheh & Adams, 2014; Kim et al., 2015; Kim et al., 2016; Joh & Plakans, 2017; Jung, 2018; Shin et al., 2019; Shahnazari, 2023).

Hu (2016) proposes younger learners “will learn foreign language better than older learners in the ultimate attainment, though older learner is regarded as fast and efficient language learner” (p.2167). Older learners tend to grasp grammar and vocabulary quickly due to their cognitive maturity. Conversely, younger learners often demonstrate a cognitive advantage in achieving native-like pronunciation and using the language authentically. The changes in WM capacity happen across different age groups. Gathercole et al. (2004) conclude that “the capacity of each component increases linearly from age 4 to early adolescence” (p.188). As children grow older, their WM capacity gradually expands, potentially enhancing their language processing ability.

In Kim’s (2010) study, she compared the utilization of visual strategies in learning to read Chinese characters among three groups: L1 Chinese child readers, L1 English child readers, and L2 Chinese adult learners. The study revealed noteworthy differences in their approaches to character learning. It was found that L1 Chinese child readers tend to stay in the visual stage for a longer duration compared to L1 English child readers. This prolonged visual stage is attributed to the phonetic opacity of the Chinese writing system and the distinctiveness of its orthographical features. As L1 Chinese and L1 English learners get mature, they transition toward a more phonetically driven stage. This cognitive development enabled them to effectively balance the utilization of both visual and phonetic cues in the reading process.

On the other hand, L2 Chinese adult learners demonstrate a unique pattern. According to Kim (2010), for L2 Chinese adult learners, “the visuospatial WM factor only correlated with this distinctive type with its visual manipulation, and not with any of the other types” (p.53). This suggests that as L2 Chinese adult learners advance in their learning, they harness their improved WM capabilities and cognitive development to approach the acquisition of Chinese characters in a more adaptable and strategic manner. As Kim (2010) explains, “Adults’ cognitive abilities seem to be adapted to disregarding unnecessary information and responding to the most relevant and the most efficient information in the target system, whereas children’s cognitive processing tends to react to any stimulus” (p.78).

“As a crucial stage characterized by accelerated WM development” (Ahmed et al., 2022, p.1), WM has been identified as a critical component in the realm of L2 learning for young adolescents, especially in the context of reading comprehension (Walter, 2004; Bailer et al., 2013; Shibasaki et al., 2015; Chang et al., 2019). Adolescence represents “a time period during which the brain exhibits tremendous structural changes” (Raznahan et al., 2011, as cited in Isbell et al., 2015, p. 2), and during this certain period of time, WM undergoes significant growth. Isbell et al. (2015) explain “visual WM capacity shows a prolonged development in adolescence, similar to the trajectories observed in other aspects of working memory, as well as various other cognitive abilities” (p.7). Reading comprehension in young adolescents typically “involves the memorization of encountered information, inference and temporary storage of this information, retrieval of the storage information from long-term memory, and integration of new and existing information” (Daneman & Hannon, 2007, as cited in Chang et al., 2019, p.467), thus it is during this development stage that young adolescents especially rely on WM support to engage in L2 reading comprehension.

As one of the factors that influence the process of L2 acquisition, age-related differences exist between young and older learners in L2 learning. While there is a

comprehensive understanding of the broader influence of age on L2 learning and the specific effects of WM on L2 reading comprehension, there is a noticeable gap in research concerning the young adolescent age group. Hence, it is imperative for researchers to allocate more focus and conduct thorough investigations within the specific developmental phase to uncover the intricacies of L2 learning.

L2 Proficiency Level

L2 proficiency level significantly influences the WM effect in L2 reading comprehension. Higher levels of L2 proficiency and a greater WM capacity contribute positively to L2 reading comprehension, whereas, low levels of L2 proficiency and limited WM capacity may pose challenges.

Proficiency levels of both L1 and L2 enact in how WM impacts L2 learning. A higher level of L1 proficiency can provide a stronger foundation for L2 learning. When learners establish a solid foundation of their L1, then they are able to leverage their knowledge and skills of L1 and apply them to their L2 learning. Therefore, the interaction between L1 and L2 proficiency and WM capacity is related to the learning outcomes of L2. The more automaticity and fluency L2 learners can develop in their L2 processing, the more they are able to gain proficiency in their L2.

Learners with low L2 proficiency levels require a higher cognitive load and more WM resources during the process of decoding the language, understanding vocabulary and grammar, and comprehending the content. In this scenario, their capacity to retain information or engage in high-order thinking may be limited. On the other hand, learners with higher L2 proficiency levels are likely to experience a lower cognitive load during language processing. This reduced cognitive load helps them free up some WM resources for more sophisticated language tasks or high-order thinking activities.

Studies have discussed the influence of L2 learner proficiency levels on the impact of WM in L2 learning (Chun & Payne, 2004; Leiser, 2007; Alptekin & Erçetin, 2009), yet yielded mixed results. Research findings indicate that there is a stronger association between WM and L2 reading comprehension at lower proficiency levels compared to those at higher proficiency levels. For example, Alptekin and Erçetin (2009) introduce that “L2 literal reading could be associated with WM capacity only for readers with low L2 proficiency levels because of these readers’ propensity for text-based processing” (p.636). Shahnazari-Dorcheh and Adams (2014) investigate that “there was a significant correlation between the reading measure and WM composite ($r=.501^*$, $P<.05$) at the beginning level” (p.28). Once again, Shahnazari (2023) prove that “at the lower proficiency level, WM capacity played a large role in explaining individual differences in L2 reading comprehension, whereas it played no significant role at the higher levels of proficiency” (p.12). These conclusions arise from the observation that as learners attain higher levels of proficiency in their L2, their L2 language processing becomes increasingly automatic and efficient, relying less on WM resources. However, both Lesser (2007) and Shin et al. (2019) hold the common belief that L2 learners with higher WM capacity can capitalize on background knowledge to achieve deeper comprehension than L2 learners with lower WM capacity. Additionally, Joh and Plakans (2017) posit that “L2 learners benefit from their WM only when they have a substantial command of target language structures and vocabulary” (p.115), which implies that WM substantially predicts enhanced L2 reading comprehension, particularly at higher proficiency levels.

Regarding Chinese as L2 learning, Kim et al. (2016) make the conclusion that L2 proficiency is the predictor of speed in reading new characters. “When reading unfamiliar characters, L2 learners with more vocabulary knowledge could retrieve pronunciation information they previously acquired from phonetics or orthographic neighbors faster than

those with less vocabulary knowledge” (Kim et al., 2016, p.1427). This observation emphasizes the benefit of attaining higher proficiency levels and higher WM capacity, especially in the context of handling complex linguistic tasks, such as recognizing Chinese characters in an L2 learning environment.

The diverse findings across various studies shed light on the nuanced nature of WM and L2 reading based on the factor of L2 proficiency levels. It is evident that elevated L2 proficiency, when combined with a greater WM capacity, contributes significantly to L2 reading. This advantage stems from their ability to efficiently process and store information while simultaneously navigating the intricacies of an L2. Nonetheless, learners with lower L2 proficiency and limited WM capacity will face more complicated challenges in the inclusive classroom when they confront language tasks that demand higher cognitive processing loads. The constrained cognitive capacities they possess can hinder their capacity to thoroughly grasp and actively engage with L2 content, potentially resulting in decreased comprehension. Acknowledging these nuances can guide educators in customizing their instructional methods to better meet the needs of a diverse range of L2 learners.

Prior Knowledge

Another significant factor influencing the WM effect in L2 learning is prior knowledge. Within the domain of L2 acquisition, prior knowledge in conjunction with WM has been found to exhibit a relationship with L2 reading comprehension.

Researchers have extensively investigated the combined impact of WM capacity and prior knowledge on cognitive performance in general. Leiser (2007) highlight that “possessing relevant background knowledge promotes better L2 reading comprehension” (p.253), and “high and medium WM learners outperformed low WM learners only if they were familiar with passage topics” (p.255). Alptekin et al. (2014) explain that “WM as a limited-capacity system, with its dual functions of processing and storage, plays a

fundamental role in reading comprehension because readers must retain available previous information while incorporating new information” (p.536).

Indeed, Alptekin and Erçetin (2011) manifest that “L2 readers’ familiarity with textual content tends to improve their comprehension, in particular, their inferential understanding, which results from knowledge-driven processes” (p.237). However, it is essential to emphasize that this familiarity does not significantly impact the literal understanding of L2 reading. This distinction can be attributed to the fact that lower-level operations in literal understanding do not require drawing upon domain knowledge or engaging in critical thinking.

In general, prior knowledge, working alongside WM in L2 learning, functions as a foundational support system that enhances the efficiency and depth of L2 learning. Prior knowledge encompasses the wealth of information and experiences L2 learners have accumulated before embarking on the acquisition of new knowledge. On one hand, prior knowledge operates as a cognitive bridge between what learners already know and what they are trying to understand or acquire in L2. It enables L2 learners to reduce the cognitive load required for processing new information, allowing learners to allocate their cognitive resources more efficiently and comprehending the new L2 content at a deeper and more meaningful level. Furthermore, the repository of prior knowledge empowers learners to engage in higher-level cognitive operations. By drawing connections between their existing knowledge and the new L2 content, learners can foster a more holistic and integrated understanding of the language. It is this dynamic interplay between prior knowledge and WM that underlines the essence of effective L2 learning and comprehension.

Conclusion

In summary, this chapter presents a qualitative meta-synthesis of a selection of research addressing the relationship between WM and L2 reading comprehension. The findings of this synthesis indicate a positive relationship between WM and L2 reading comprehension. WM plays a crucial role in multiple facets of reading comprehension, with L2 learners possessing greater WM capacity tending to perform better in comprehending and retaining information from the L2 written texts, and vice versa. The subcomponents of WM, such as phonological loop and visuospatial sketchpad, have been proven to be the storage and processing factors that affect L2 reading in the context of languages like Chinese in virtue of its visual and phonological complexities of character processing. In addition to WM, other factors, such as individual variabilities including developmental age, L2 proficiency level, and learners' prior knowledge also contribute to L2 reading comprehension. This literature review provides a comprehensive understanding of the development within the psycholinguistic realm concerning the interplay between WM and L2 reading comprehension.

Chapter Four: Results and Discussion

This chapter presents the results of this meta-synthesis study that was conducted to explore the relationship between WM and L2 reading comprehension by reviewing the existing research. The primary objective of the study is to review recent studies and derive insights into how WM influences the comprehension of written texts in an L2 context for L2 learners. Specifically, this chapter will also place a distinct emphasis on the relevance of Chinese language learning within the context of Grade 9-12 students in English medium international schools based in Thailand, while also considering the dynamics of an inclusive learning environment. By addressing the main research question and its two sub-questions, this chapter will provide a comprehensive overview of the key findings gleaned from the extensive literature review.

Results

Main Research Question: What is the relationship between WM and L2 reading comprehension?

The central inquiry guiding this meta-synthesis study is: “What is the relationship between WM and L2 reading comprehension?” The hypothesis that there is a positive relationship between WM and L2 reading comprehension aligns with the existing body of research in the field (Walter, 2004; Leaser, 2007; Alptekin & Erçetin, 2009; Chang et al., 2019; Shahnazari, 2023).

The relationship between these two cognitive processes has been a topic of interest for researchers in the domains of psychology, linguistics, and education. Results from the literature review indicate the following two key responses to this question:

First, WM is vital for both lower-level and high-level processing in L2 reading.

At lower-level processing in L2 reading, which includes the visual recognition of letters or characters, and the usage of phonological and orthographic information, the sub-

components of WM collaborate and interact with each other. The central executive operates actively to retrieve relevant information from the existing knowledge, visuospatial sketchpad WM aids in managing the visual complexity of the written language, and phonological WM has been proven significantly affect this stage of learning regarding its processing of the sounds of language, linking them to written symbols, and maintaining these phonological representations for understanding.

In terms of the high-level processing in L2 reading, especially when dealing with complex sentences, relies heavily on the capacity of WM. The ability to efficiently parse and comprehend intricate sentence structures is closely tied to an individual's WM capacity. When it comes to cognitively demanding reading tasks like inferential reading, which is more complex than literal comprehension, it requires L2 learners to hold and manipulate information from different parts of the text, integrate it with their prior knowledge, and engage in high-order cognitive processes to extract meaning, WM has become a key determinant of successes in the reading task. The central executive continues to coordinate the information integration, allocate attention, and manage cognitive load. Phonological WM also aids in holding and processing phonological representation of the words and phrases, retaining and deriving the textual meaning, and maintaining continuity as progresses through the text. Acknowledging the roles of central executive and phonological components as they pertain to higher-level processing, the research on the role of visuospatial WM in this area warrants further exploration.

Second, L2 reading comprehension is a multifaceted process, apart from WM, also involves the interplay of individual factors, such as learners' developmental age, L2 proficiency level, and learners' prior knowledge which also contribute to the overall language comprehension process. Individual differences function as factors shaping the formation of understanding during complex tasks. L2 proficiency level and prior knowledge stand out as

the main variables that affect the effect of WM in L2 reading. The impact of WM on L2 reading comprehension can vary based on the level and relevance of learners' existing knowledge about the topic they read (Walter, 2004; Lesser, 2007; Alptekin & Erçetin, 2009; Shin et al., 2019). L2 learners with substantial prior knowledge about the topic, integrate the new information with their existing background knowledge, and this integration process tends to require less WM capacity compared to L2 learners who lack the necessary background knowledge.

The contribution of WM to L2 reading comprehension varies across different studies. The complexity of L2 reading comprehension can lead to different findings across studies due to the different focus of the aspects of L2 reading, yet there is strong evidence indicating WM's significant impact on L2 reading comprehension. In addition, these insights provided through this study review enhance understanding of why L2 learners have varying levels of success in comprehending L2 texts within the inclusive classroom.

Research Sub-Question 1: How Does WM Impact L2 Reading Comprehension Across Proficiency Levels?

A secondary question addressed in this study is: "How does WM impact L2 reading comprehension across proficiency levels?" L2 proficiency level is a moderating variable in the relationship between WM and L2 reading, and the relationship differs across different proficiency levels. According to the review of the studies (Walter, 2004; Linck et al. 2014; Shahnazari-Dorcheh & Adams, 2014; Kim et al., 2016; Joh & Plakans, 2017; Shahnazari, 2023), the impact of WM on L2 learning and processing varies with L2 proficiency levels.

The hypothesis of this research study posits that higher proficiency and larger WM capacity confer advantages in L2 reading, while lower proficiency and limited WM capacity present challenges. However, the results from these studies show inconsistent variations. Linck et al.'s (2014) research suggests that both low and high proficient learners equally

benefit from WM capacity, which implies WM was related to L2 reading to a similar degree across proficiency levels. Studies (Alptekin & Erçetin, 2009; Shahnazari-Dorcheh & Adams, 2014; Shahnazari, 2023) also yielded the result of the association between WM and L2 reading comprehension among learners of lower proficiency. In this case, “low-proficiency L2 learners rely on WM more than high-proficiency L2 learners during reading tasks” (Shahnazari-Dorcheh & Adams, 2014, p.29), because L2 learners with higher proficiency tend to depend on their language knowledge and automaticity in the reading process, which can alleviate the cognitive load on WM during reading. On the contrary, Joh and Plakans (2017) believe the impact of WM in L2 reading exists among higher-proficiency level learners, as “L2 readers benefit from their WM only when they have a substantial command of target language structures and vocabulary” (p.115).

Overall, L2 proficiency level, serving as a variable, affects the relationship between WM and L2 reading comprehension, and this dynamic shifts across different proficiency levels. Nevertheless, the study’s findings reveal discrepancies in these associations, emphasizing the imperative for further exploration in this domain.

Research Sub-Question 2: What Impact Does the Visuospatial Sketchpad Have on Mandarin L2 Reading Comprehension?

Another sub-question considered is: “What impact does the visuospatial sketchpad have on Mandarin as L2 reading comprehension?” The hypothesis posits that in a language characterized by logographic characters like Chinese, the visuospatial sketchpad’s involvement is particularly pronounced due to the visual complexity of the writing system.

During this literature review, it was observed that there is a general scarcity of studies on this topic. As a result, the synthesis of this question relies on a limited pool of research studies. The results of this research reflect that Chinese as L2 learners with higher visuospatial WM can build a solid foundation in basic character recognition and meaning

association at the initial stage of learning, which is essential for later comprehension and literacy. However, when processing logographic characters in reading comprehension, not only visuospatial sketchpad WM but several other cognitive processes are involved in the meantime. L2 reading comprehension indeed requires integration with multi-aspects of WM to coordinate various cognitive tasks during reading.

Despite the above findings have shed light on the relationship between visuospatial sketchpad WM and L2 reading comprehension, it is evident that further research is warranted in this area. Baddeley (2015) highlights the role of visuospatial sketchpad WM in learning novel orthography or visually complex scripts that would benefit from further research. Moreover, Kim et al. (2016) also emphasize that “in contrast to other components of WM, the contribution of visuospatial sketchpad WM to L2 word learning remains relatively unexplored” (p.1415). Expanding the body of knowledge on how visuospatial sketchpad WM influences various aspects of L2 reading, including word learning and comprehension will help to build a more comprehensive understanding of the cognitive processes at play during L2 reading. In addition, these findings emphasize that L2 reading comprehension is a multifaced process influenced by various individual factors beyond WM. Taking a holistic approach that considers a range of cognitive and linguistic variables will contribute to a more complete and nuanced understanding of L2 reading comprehension.

Pedagogical Implications for Inclusive Classrooms

Conducting this literature review has revealed a common consensus: L2 learning is an inherently complex process, made even more intricate by the presence of L2 learners with varying WM capacities in an inclusive educational setting. Understanding the critical role of WM in L2 reading comprehension, especially in the context of Chinese L2 reading, educators can tailor their instructional approaches to accommodate and support L2 learners with diverse

WM capacities. By doing so, they can enhance the prospect of optimizing language learning outcomes for all students, ensuring that each learner has the opportunity to succeed in their Chinese language acquisition journey.

The subsequent sections will explicitly discuss the following pedagogical implications: considerations for reading instructions, interventions in WM, chunking information, repetition, and the use of active learning.

Considerations for Reading Instructions

In order to pave the way for L2 learners with diverse WM capacities to gain reading comprehension, the findings from this study point to several considerations for reading instructions.

First, customizing reading materials to cater to the diverse backgrounds and abilities of L2 learners is a critical aspect illuminated by the findings. Recognizing that personal experience, prior knowledge, and cultural relevance significantly impact comprehension can enhance engagement and comprehension by making the reading experience more relatable and meaningful for L2 learners.

Second, adapting teaching strategies and offering support for L2 learners to navigate reading tasks is another crucial consideration. As revealed in the research, WM capacity impacts both literal and inferential comprehension. Thus, educators can keep in mind the cognitive load imposed by reading tasks and consider scaffolding techniques to support learners with limited WM capability.

Finally, recognizing the critical significance of tailoring reading tasks to align with the varying complexities of L2 reading materials is essential to bear in mind. It is crucial to acknowledge the different texts and tasks place differing cognitive demands on L2 learners. This approach will ensure L2 learners engage with appropriately challenging reading materials.

When making reading decisions for L2 learners, it is important to take into account cognitive capacities, individual learner needs, and the intricacies of the reading material. By incorporating these insights, educators can foster a more effective and inclusive language learning environment for L2 learners.

Interventions in WM

WM interventions encompass structured programs or strategies specifically designed to either enhance an individual's WM capacity or optimize the utilization of their existing WM capacity. These interventions are particularly tailored for learners with limited WM capacity in inclusive classroom settings, aiming to improve cognitive functioning and support learners in effectively managing tasks that rely on WM.

WM, also known as a component of foreign language aptitude, has been found to be subject to improvement or development. L2 learners with limited WM capacity can improve their WM capacity through targeted training. Considering the potential for educational interventions to support L2 learners in improving their reading skills by addressing the role of WM, it becomes pertinent to conduct intensive WM training sessions. Such training can prove beneficial for L2 learners with limited WM capacity, aiding in the improvement of their WM.

WM training has been categorized into two distinct types based on its nature: domain-general WM training and domain-specific WM training. Domain-general training targets improvements in central executive functioning while processing information. The WM training program focuses on the executive processes involved in reading to enhance the reading comprehension abilities of normally developing L2 learners. The experiment by Berger et al. (2020) has shown substantial improvement in reading comprehension tasks after WM training, and also claim that "adaptive WM training during class improves not only

children's WM capacity but also has far-transfer effects on their geometry and reading skills" (p.26).

Domain-specific WM training includes verbal and visuospatial WM training. Pham and Hasson (2014) support that "verbal WM is a strong predictor of reading performance" (p.467). WM training has been considered one of the interventions to enhance academic performance. However, regarding the effect of WM training, evidence of significant improvement in WM mainly comes from the laboratory context. Holmes and Gathercole (2014), in their study, mention that "the training is implemented by experienced researchers under optimal and often resource-intensive conditions that cannot feasibly be achieved in non-research usage" (p.441).

Rather than implementing WM training within the inclusive classroom, WM interventions can also concentrate on optimizing the utilization of the current working memory capacity. In addition to implementing WM training, it is equally crucial for educators to recognize the wide spectrum of WM capacities present in the classroom and adopt a multi-step approach to effectively support L2 learners with limited WM capacity. To address the challenges that Grade 9-12 students face in Chinese L2 reading, educators can consider implementing the following approaches to cater to optimizing the utilization of existing WM capacity.

Chunking Information.

When delivering new content to students, educators can employ the cognitive strategy of chunking information into smaller, more manageable parts, especially for those with limited WM capacity. Chunking enables L2 learners to maximize their WM capacity. Instead of requiring students to process the entire content all at once, educators can break down the information into smaller units.

When chunks are formed and based on meaningful associations and are connected to prior knowledge, they not only decrease cognitive load but also leverage existing knowledge, enhance recall, and contribute to the formation of LTM. Thalmann et al. (2019) testify that “chunking frees WM capacity” (p.39), and “chunks reduce the load on WM, thereby improving memory for other information maintained concurrently” (p.44). Hence, chunking information significantly contributes to reducing the load on WM.

In terms of Chinese L2 reading characters and phrases, educators can teach learners to recognize common radicals and frequently occurring characters. This approach helps learners quickly identify and understand the characters, reducing the cognitive load associated with decoding each character in isolation. Educators can further encourage learners to recognize and process phrases or sentence structures as chunks rather than individual characters. This way, learners will swiftly grasp the meaning of a group of characters together, facilitating a smoother comprehension process in a contextual setting. When dealing with more complex Chinese L2 reading materials, educators can also start with simpler and shorter texts, progressively integrating longer and more challenging content. This approach guides students to view longer texts as interconnected chunks rather than a mass of information altogether.

Repetition.

Repetition, as a memory reinforcement technique, facilitates the transfer of information from WM to LTM. As L2 learners gain proficiency in retrieving information from LTM, the effects of repetition can alleviate the load on WM. This, in turn, allows them to process information with reduced cognitive effort, minimizing the need for extensive processing and rehearsal in WM. Educators can reinforce learning by always revisiting or repeating previously learned material over time through various channels to strengthen memory retention.

In the context of Chinese L2 learning, educators can increase exposure to commonly used characters, phrases, and sentence syntactic patterns. This exposure enables learners to recognize and understand them more fluently, facilitating automatic processing. The development of automatic recognition reduces the reliance on WM for processing individual characters, leading to better comprehension of the overall context. Activities such as flashcards, memory games, word walls, and visual aids can support Chinese L2 learners in repetitively encountering and engaging with Chinese characters and phrases, ultimately contributing to improved recognition and understanding. Concerning Chinese L2 Reading comprehension, educators have various ways to encourage L2 learners to use repetition. Learners read the same text multiple times with different purposes, such as describing the main idea, paraphrasing the new vocabulary, and discussing the key details. Exposure to repetitive language use in different contexts can also strengthen learners' adaptability and enhance their ability to apply language knowledge in diverse situations.

Use of Active Learning.

Active learning not only fosters active participation in the learning process but also keeps WM engaged. It promotes engagement and attentiveness, making the learning process more meaningful and relevant for students. Active learning activities, in particular, involve social interaction, enabling students to practice reinforcing language skills in a communicative context. Educators can integrate activities that actively engage students to use the target language in class, such as role-play exercises, real-life scenarios, collaborative problem-solving, or debates and discussions.

In Chinese L2 learning, educators can foster active learning by providing opportunities for authentic exposure to the Chinese language. Immersing students in a Chinese-speaking environment enriches their learning experience. For instance, educators can organize field trips to Chinatown, where various Chinese resources abound, providing a real-

life context for language use. This approach can help the student connect language elements to concrete situations, fostering a deeper understanding of the language and making the learning more memorable. In the realm of Chinese L2 reading comprehension, educators can introduce authentic Chinese reading materials to students. This includes newspapers, magazines, and books that reflect genuine language use. Real-world relevance enhances engagement. By incorporating these resources, educators motivate students to actively engage with the Chinese language across various contexts.

Conclusion

This chapter concludes the key findings about the relationship between WM and L2 reading comprehension based on the research results from the literature review and looks ahead to future investigations and interventions that could be implemented to support L2 learners with their limited WM capacity, particularly in inclusive classrooms. In light of the limited existing studies that cover these research topics, this chapter also functions as an advocate to educators and researchers in their continuity of pursuing further studies on the effect of visuospatial sketchpad WM in Chinese L2 reading.

Chapter Five: Conclusions and Summary Remarks

In this concluding chapter, the core findings from this comprehensive literature review are summarized and the limitations of the study are addressed. This final chapter serves as a fitting conclusion to this scholarly journey while paving the way for future research avenues, looking forward to laying the foundation for potential research trajectories in this domain.

Summary of the Project

WM is a cognitive system that temporarily holds and manipulates information while the brain is engaged in other tasks. Its limited capacity can present challenges for L2 learners, with those having greater WM capacity managing multiple tasks more efficiently than those with limited capacity, leading to difficulties in processing complex information. In an inclusive classroom, students exhibit a diverse range of WM capacities. Those with limited WM often co-exist with other issues, such as dyslexia and ADHD, but can also be a stand-alone problem. Apart from learning disabilities, external factors like stress, fatigue, depression, and sleep deprivation can also contribute to WM deficits in students.

A deficiency in WM can profoundly impact learning. As educators in an inclusive classroom setting, awareness of these matters can help educators be vigilant in identifying students experiencing WM deficits. Recognizing and understanding these challenges enables educators to provide targeted support and accommodations, fostering a more inclusive learning environment that allows all students to excel both academically and socially.

According to the results of this study, it asserts a positive relationship between WM and L2 reading comprehension. The impact of WM on L2 learning and processing varies with L2 proficiency levels. The visuospatial sketchpad WM is involved in reading comprehension while processing logographic characters at an initial stage of learning.

However, L2 reading comprehension requires the collaboration of multiple aspects of WM to accomplish the reading task. These findings provide valuable insights for Grade 9-12 students studying Chinese as an L2 in an English-medium-speaking international school in Thailand. The pedagogical implications for inclusive classrooms of L2 Chinese education involve recognizing the inherent complexity associated with L2 learning, especially in the presence of diverse WM capabilities among students. Educators can tailor instructional approaches that take into account the varying capacities of WM, primarily including the implementation of WM interventions to optimize the utilization of existing WM capacity. Additionally, educators can adjust Chinese L2 reading instructions to enhance language learning outcomes for students with limited WM capacities and extend the benefits to all the other students.

Limitations of the Study

Diversity of L2

One limitation of this literature review is related to the samples of L2. The studies that are included in this literature review have widely used English as L2 samples except for a few. Given the prevalence of English as the global lingua franca and its widespread use as an L2 in different regions, it is understandable for researchers to focus primarily on English L2 learners. However, this can limit the generalizability of findings to learners of other languages. Furthermore, the specific challenges and strategies that apply to English as L2 learners may not necessarily translate directly to learners of other languages. For the purpose of a more comprehensive investigation of the effect of WM in L2 learning, it will be beneficial to be aware to include learners from different L1 and L2 backgrounds outside the Indo-European family and language whose orthography is not phonological (Walter, 2004, p. 334) which will throw additional light on this subject.

Age Group

The age group is another key variable that affects the effect of WM in L2 reading. As The age group of the participants in this literature review varies in different ranges from kindergarten to adult. The studies cover the following educational groups, primary school students, secondary school students, undergraduates, and adult learners, yet most of the researchers focus on college students (undergraduates). However, the research group of this study focuses on students from Grades 9-12 who are at an adolescent age. The role and function of WM at different stages of L2 learning development might be divergent as Shen and Park (2020) state that “the influence of WM on L2 learning and processing varies with L2 proficiency and learners’ age” (p.99). The narrow range of age among the included studies hindered the understanding of how WM evolves and influences language development over time. To gain a more comprehensive understanding, it is essential to consider learners across different developmental stages.

Scope of Research Findings

The conclusions drawn in this research are exclusively based on the studies included, and it is important to note that the findings may not comprehensively represent the entirety of the research landscape. This acknowledgment of the research limitations emphasizes the need for future investigations to consider a broader spectrum of studies to enhance the comprehensiveness and depth of our understanding of this topic.

Conclusion

This meta-synthesis study offers a valuable opportunity to examine prior research focused on the relationship between WM and L2 reading comprehension. Through this review, we have delved into the implications of teaching Mandarin Chinese to Grade 9-12 students in English medium international schools in Thailand. Notably, the investigation has

revealed that both the phonological and visuospatial components of WM significantly influence Chinese L2 reading comprehension in general, with these influences varying based on individual differences. What sets this study apart from previous research is its unique theoretical contribution to the WM and L2 reading comprehension field. Specifically, the impact of the visuospatial sketchpad on Chinese L2 reading across different proficiency levels. Despite the study's limitations, the findings of this meta-synthesis empower educators to implement effective strategies, create an inclusive atmosphere, and tailor instructions to optimize comprehension outcomes for L2 learners with limited WM capacity and for all L2 learners.

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Routledge.

Appendix A

#	Articles/ Themes	WM and L2 Processing				Impact of Individual Variability			Effects of Distinct WM Components			Training Interventions to Improve WM
	Research Questions to Focus on	What is the relationship between WM and L2 reading comprehension?				How does WM impact L2 reading comprehension across proficiency levels?			What impact does the visuospatial sketchpad have on Mandarin L2 reading comprehension?			
		WM and L2 Word Recognition and Vocabulary Acquisition	WM and L2 Sentence Processing	WM Capacity and L2 Reading Comprehension	Task Demands (Literal/ Inferential)	Age Group	L2 Proficiency Level	Prior Knowledge	Central Executive	Phonological loop	Visuospatial Sketchpad	
1.	Walter, C. (2004).		*				*			*		
2.	Leeser, M. J. (2007).	*			*			*				
3.	Fontanini, I., & Tomitch, L. M. B. (2009).			*	*			*				
4.	Alptekin, C., & Erçetin, G. (2009).				*							
5.	Kim, S. A. (2010).	*				*				*	*	
6.	Alptekin, C., & Erçetin, G. (2010).			*	*							
7.	Alptekin, C., & Erçetin, G. (2011).			*	*			*				
8.	Chung, K. K., & McBride-Chang, C. (2011).	*				*				*		
9.	Choi, S. (2013).	*			*							
10.	Bailer, C., Tomitch, L. M. B., & D'ely, R. C. S. F. (2013).	*							*			

11.	Tsai, A. M. (2014).									*	*	*
12.	Shahnazari-Dorcheh, M., & Adams, R. (2014).			*			*			*		
13.	Shibasaki, H., Tokimoto, S., Ono, Y., Inoue, T., & Tamaoka, K. (2015).	*	*					*				
14.	Kim, S. A., Christianson, K., & Packard, J. (2015).	*								*	*	
15.	Kim, S. A., Packard, J., Christianson, K., Anderson, R. C., & Shin, J. A. (2016).	*					*			*		
16.	Joh, J., & Plakans, L. (2017).						*	*				
17.	Jung, J. (2018).				*					*		
18.	Chang, X., Wang, P., Cai, M. M., & Wang, M. (2019).			*					*	*		*
19.	Shin, J., Dronjic, V., & Park, B. (2019).			*				*				
20.	Huang, L., Ouyang, J., & Jiang, J. (2022).	*							*			
21.	Pretorius, M. J., Le Roux, M., & Geertsema, S. (2022).		*							*		
22.	Shahnazari, M. (2023).			*			*					
		9	3	7	7	2	5	6	3	10	3	2