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工作記憶和英語為外語的閱讀兩者間的關係--以嘉義市一所國中為個案

Relationship between Working Memory and EFL Reading Comprehension: A Case Study of Chiayi Junior High School Students

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RELATIONSHIP BETWEEN WORKING MEMORY AND EFL READING COMPREHENSION: A CASE STUDY OF CHIAYI JUNIOR HIGH SCHOOL STUDENTS

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碩士論文提要

論文名稱:工作記憶和英語為外語的閱讀兩者間的關係

--以嘉義市一所國中為個案

指導教授:余明忠教授

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論文提要內容:

本研究旨在探討工作記憶對英文閱讀理解的相關性，而其中更細分去看工作記憶對字面理解和推論理解的影響。另一方面，測量工作記憶的閱讀廣度作業(RST)在研究工作記憶和閱讀理解時常被忽略不同作業測量是否對研究結果有所影響，而廣為研究採用的是辨識閱讀廣度(recognition-RST)以及再認閱讀廣度(recall-RST)。因此，本研究除了探討工作記憶對英文字面和推論理解的相關性，也欲比較此兩種不同閱讀廣度作業對於工作記憶和閱讀理解的關係是否有所不同。

實驗對象是嘉義市立研究者任教的一所國中，全校 37 個班級，其中抽出可以配合研究過程的學生，總計 190 人，來自七個班級。這些班級的學生都有各自原本班級要進行的課程，因此為了施測方便，以班級為單位，不同班級完成不同的工作記憶廣度，會使研究有辦法進行，因此，本研究並無設定特定的分組規準，七個班級會分兩頭取得各自的工作記憶廣度—也就是四個班級完成再認閱讀廣度(recall-RST)以及閱讀測驗; 另外三個班級辨識閱讀廣度(recognition-RST)以及閱讀測驗。其中使用的閱讀測驗旨在評量參與者字面閱讀理解和推論閱讀理解的能力。研究結果顯示再認閱讀廣度的工作記憶對字面閱讀理解的相關性、和推論閱讀理解的相關性、和整個閱讀理解的相關性皆未達顯著相關性。另外，辨識閱讀廣度的工作記憶對字面閱讀理解的相關性、和推論閱讀理解的相關性、和整個閱讀理解的相關性也皆未達

顯著相關性。此次研究結果和 Ruppe 等人(2006)以及 Sweller(1994) 的研究一樣，主張工作記憶和字面閱讀理解關係不大。至於推論閱讀理解部分，本研究針對工作記憶和推論閱讀理解的相關性和其他研究則不符，許多研究主張工作記憶對高階認知學習(high-level cognition activities) 有極大的幫助 (Anderson et al., 1996; Altepkin & Ercetin, 2001; Baddeley, 2012; Conway & Engle, 1994; Daneman & Hannon, 2007)。此處和其他研究主張意見分歧，可以從 Gathercole 和 Alloway (2007) 的說法來解釋，工作記憶對於學習認知活動的相關性是有所限制的。談及影響工作記憶和推論理解或是與其他較具挑戰性的認知活動時，尚有很多相關因素在研究中需要考量，例如參與者的閱讀技巧、專注力和背景知識。最後，本研究欲探討辨識閱讀廣度(recognition-RST)以及再認閱讀廣度(recall-RST)對於工作記憶再閱讀的影響力是否有所差別，迴歸分析表示此兩種閱讀廣度測到的工作記憶對閱讀的影響力無顯著差異; 針對這點，有些學者主張閱讀廣度雖不同，但都能測驗到相同的工作記憶(Turner & Engle, 1989)，然而也另外有學者主張辨識和再認閱讀廣度測驗到的工作記憶有所不同(Alptekin & Ercetin, 2009; Unsworth & Engle, 2007)。因此未來需要更完善的研究設計和實施，排除其他影響工作記憶和閱讀相關的因素，例如分組規準、參與者的閱讀技巧、背景知識等，才能更加確定工作記憶對字面和推論理解的影響力，以及不同的工作記憶測量工具對工作記憶影響力的差異。

Abstract

This study examined the influence of working memory (WM henceforth) on literal and inferential comprehensions in second language (L2) reading. WM refers to individuals' cognitive process in which new and old information is temporarily stored and simultaneously processed. The strength of WM enables individuals to accomplish complex tasks, such as reading and reasoning. It sounds invincible, but it has its limitation (Baddeley, 2000; Conrad & Hull, 1964). The capacity of WM (WMC) represents the abstract concept of WM and is often measured with reading span tasks (RSTs). Also this study was aimed to investigate whether the influence of WM on reading comprehensions (RC henceforth) was different when WM is measured with different RSTs. According to Alptekin and Ercetin (2009), the difference of measurement tasks about WMC is often not taken into consideration in research. Thus, the investigator measured the participants' WMC with two main RSTs, a recall-RST and a recognition-RST, and the results were later analyzed with their performance of L2 literal and inferential comprehensions.

The participants in this study were 190 students from 7 classes in a Chiayi City Junior High School with a total of 37 classes. Due to the limitation of course schedules at school, participants had to attend their own classes. The investigator decided to group entire classes into same WM group in order to carry out the study. Thus, no specific grouping criterion was applied—the participants from three classes accomplished a recognition-RST and a RC test; the participants of the rest accomplished a recall-RST and a RC test. The test of RC contained four passages with five literal and five inferential RC questions, and was designed to assess participants' ability to read literally and inferentially.

The findings showed that WMC measured with a recall-RST had no correlations with participants' literal, inferential and overall RC. In the recognition-RST group of WM,

the correlations of WM and RC was not significant, either. The current study and previous studies all suggested that WMC had no influence on literal RC (Rupp et al., 2006; Sweller, 1994). However, the result of WMC in this study did not successfully demonstrate positive correlation with inferential RC, which was against previous findings (Anderson et al., 1996; Altepkin & Ercetin, 2001; Baddeley, 2012; Conway & Engle, 1994; Daneman & Hannon, 2007). This result suggested that it was not easy to relate WM to the performance of inferential RC. Though the strength of WM is highly related to complex tasks, according to Gathercole and Alloway (2007), WM is unfortunately limited in certain ways regarding its influence on cognitive activities. Relevant factors, such as participants' reading skills, attention to each current task and background knowledge, if not controlled, might interfere with the positive influence of WM on RC. Further research is warranted to fully examine the relationship between WM and RST in terms of one's ability to read literally and inferentially.

CHAPTER ONE

INTRODUCTION

"The eye sees only when the mind is prepared to comprehend." –Henri Bergson

Many researchers have argued that working memory (henceforth WM) is predictive of reading comprehensions and accounts for language performance (Altepkin & Ercetin, 2010; Anderson, Reder, & Lebiere, 1996; Baddeley, 2012; Conway & Engle, 1994; Daneman & Carpenter, 1980; Daneman & Hannon, 2007; Miyake & Friedman, 1998; Walter, 2004). WM refers to a systematic mechanism or an ability to maintain information active while processing the very or another piece of information simultaneously (Baddeley & Hitch, 1974; Baddeley, 2003; Daneman & Carpenter, 1983). WM flexibly supports daily cognitive activities that require storage and manipulation of information, such as mental mathematics and reading comprehension (henceforth RC). WM correlates with RC mostly because it helps readers to efficiently store information from texts, such as syntactic or semantic messages, and to coherent all the information with coming messages in following texts (Daneman & Carpenter, 1980). Though the relationship between WM and RC has been extensively studied, most works in this field study seldom involve EFL (English as a foreign language) learners or and has assessed RC as a single construct, providing limited data and neglecting the multiple levels of RC (Daneman & Carpenter, 1980; Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Engle et al., 1992; Ericsson & Delaney, 1999). It was only until recently that more researchers have come to pay attention to "its multilevel representational architecture and the role played by each level in reading comprehension" (Alptekin & Ercetin, 2009, p.628). It could be concluded that WM has significant influence on reading comprehension as one single construct and also on it as a multilevel construct. But further investigation is necessary in terms of the relationship between WM and language comprehension as a multilevel construct.

In Taiwan, the Basic Competency Test for junior high school (BCT) was implemented from 2001 to 2013. In 2014 it was replaced by a new entrance examination to senior high school, Comprehension Assessment Program for High School Students (CAP). One main difference between the English reading comprehension tests of the CAP and those of the BCT is the proportion of comprehension questions ranging from basic ones to difficult ones; more challenging comprehension questions, such as making inference, are included. According to the official report of Item Difficulty Description for CAP English Comprehension Test from Ministration of Education (MOE) in 2014, this reform is aimed to better discriminate the English proficiency of future senior high students and to assess test-takers' English competence in a more comprehensive way. By increasing the proportion of inferential reading comprehensions, the CAP could assess test-takers' abilities to infer information which is not literally stated in texts. Making inferences requires high-order thinking ability in which readers must decode details and infer implicit messages beyond literal messages. In sum, the CAP English test measures reading comprehension both as a global construct and as multilevel representations.

I am a 7th and 9th grade teacher in a small junior high school in Chiayi City for almost 9 years and the students from the community vary in their academic interest and proficiencies. Along with the reform of CAP, a strong urge arises to improve students' overall reading comprehension abilities. In the previous English exams of BCT, some students who had taken the BCT exam had claimed that it was effortless to choose the right answers because some reading comprehension questions only required them to recognize some factual clues from the text. Others had claimed they would be able to get high or satisfying scores based on their instinct or common sense. As an English teacher in junior high school where most students find it difficult to survive the newly-reformed English test of the CAP, it is my interest in this study to investigate whether WM could benefit junior high students in terms of making successful and comprehensive understanding about the CAP English comprehension test. Hence, the predictive power of

WM on RC intrigued me to learn about the essential elements which would foster students' comprehension abilities.

Though many studies show the strong correlation between WM and RC, inadequate research has involved Taiwan EFL high school students as participants. The research regarding the interaction of WM and L2 reading have mostly investigated advanced English learners with TOEFL scores 500 or more or elementary students in Holland, Italy, US, Japan, and Mainland China (Alptekin & Ercetin, 2010; Carretti, Borella, Cornoldi, & De Beni, 2009; de Jonge, 1996; Friedman & Miyake, 2004; Sawyer & Harrington, 1992). Some studies have involved pre-readers (Hannon & Frias, 2012), children (Cain, Oakhill & Bryant, 2004), adolescents (Cromley & Azevedo, 2007), and seniors (Hannon & Daneman, 2009). Due to the limited sampling in this field of WM and RC, I think it would be worth investigating the power of WM on reading comprehension by involving my students as participants in studies about WM and RC.

Besides the scant studies involving high school students, English is learned as a second language for the target participants in my study. Studies have shown significant differences between first language (L1) and second language (L2) when it comes to the interaction between WM and language performance. It is indicated that the discrepancy or the difference between one's L1 and L2 working memory capacity (WMC[1]) decreases when one's L2 knowledge increases (van den Noort, Bosch, & Hugdahl, 2006; Service Simola, Metsänheimo, & Maury, 2002). Junior high school students begins to gain more L2 knowledge than what they learned in elementary school English courses—English learners start to learn more about using the language in junior high school English. Due to the reasons stated above, it was the researcher's interest to investigate how WMC interacts with RC performance of students with elementary or intermediate English

[1] Here WM refers to the abstract mental system that is devoted to information maintenance and process while WMC refers to the specific capacity that represents how much mental space individuals possess.

proficiency, particular those junior high school students from my school in Chiayi City. In my English class, I teach students about language usage and language use. I include lots of communicative activities to involve students to become active language users. I have joined many as TESOL workshops or seminars as possible in order to improve my instruction and the efficiency of student's learning. To involve students in joy of learning English is always one of my expectations in designing my courses. Some students following every step and suggestion in my class sometimes still found it overwhelming to fully understand the challenging comprehension texts in newly-reformed CAP exams. Besides teaching the knowledge about English and including creative teaching activities, I wondered what else I could do to help students feel less frustrated and more confident in RC. As a teacher in high school, I was intrigued by the predictive power of WM on reading comprehension discussed among numerous studies.

To date, several studies have shown that WM is a limited-capacity system that serves two functions—to store information temporarily and to process information simultaneously (Baddeley & Hitch, 1974; Baddeley, 2003; Daneman & Carpenter, 1983). To measure the capacity of WM or WMC, a dual-task is often adopted to measure the functions of storage and process and is known as reading span tasks (RSTs). However, studies investigating the influence of WM on RC have adopted different scoring methods and measurements. In other words, the difference of WMC measurement tasks is often not taken into consideration in research. In other words, the factor of different degrees of working memory resources underlying different cognitive tasks is usually overlooked in research (Alptekin & Ercetin, 2009). Some researchers adopt recall-RSTs which require participants to memorize and later to spell the ending words (Harrington & Sawyer, 1992; Miyake & Friedman, 1998; Osaka & Osaka, 1992) while other researchers adopt recognition-RSTs which require participants to memorize and later to recognize ending words of each sentence from a multiple-choice test (Chun & Payne, 2004). These two types of WM measurement, a recall-RST and a recognition-RST, both require participants to store and to process information simultaneously. Irrespective of WMC measurement types (recall-RST and recognition-RST), according to Turner and Engle (1989), RSTs of all kinds could tap the same variation in reading comprehension. When taking recognition-RST, participants judge the grammaticality of presented sentences and recognize the endings words of the presented sentences from a provided multiple-choice test. In this case, a recognition-RST is to tap the storage function of WMC in which participants identify the externally presented cues. On the other hand, recall-RSTs also tap the storage function of WMC. When taking a recall-RST, participants also judge the grammaticality of presented sentences but they have to memorize and write down the ending words. Hence, in a recall-RST, the ending words in each sentence that participants memorize are internally generated cues for later free recall. In a recognition-RST, participants recognize the ending words from externally presented cues (Unsworth & Engle, 2007). Since recall-RSTs and recognition-RSTs are commonly used in studies about WMC and its influence on RC, this study was aimed to investigate whether these two types of RST would make a difference on the influence of WM on RC.

This paper aimed to study the relationship between L2 WMC and L2 reading comprehension in the dimensions of literal and inferential comprehensions when L2 WMC is measured with two measurement task types. The research questions are:

(1) Is there a significant relationship between L2 WM recall reading span score and English comprehension accuracy in terms of L2 literal and inferential reading?

(2) Is there a significant relationship between L2 WM recognition reading span score and English comprehension accuracy in terms of L2 literal and inferential reading?

(3) Will the influence of L2 WM on L2 RC be different if WMC is measured via these two types of RST, recall-RST and recognition-RST?

Based on the review of literature, hypotheses regarding the research questions are as follows:

(1) L2 WMC[2] measured in a recall-RST and a recognition-RST is not expected to have a significant relationship with L2 literal RC.

(2) L2 WMC measured in a recall-RST and a recognition-RST is expected to have a significant relationship with L2 inferential RC.

(3) Compared with a recognition-RST, MWC measured in a recall-RST is expected to be significantly correlated to the L2 RC performance.

[2] The capacity of WM is called WMC, which represents the abstract mental concept of WM. And WMC is often measured with reading span tasks (RSTs).

CHAPTER TWO

LITERATURE REVIEW

As mentioned above, some researchers treat RC as one single construct when it comes to WM and RC. Instead of treating RC as one single construct, the first part of literature review demonstrates the urge to treat RC as a multilevel construct when it comes to the relationship between WM and RC. This chapter first provides theoretical concepts of RC and its multiple levels. Then, the following part presents thorough and relevant literature review concerning WM. Three aspects in the research questions—L2 WM, two commonly used WM tasks along with L2 literal and L2 inferential comprehensions—were well elaborated.

Reading Comprehension

Overview of Reading Comprehension

What makes a good reader a good reader? What exactly happens in readers' mind during reading processes? Readings are written messages from the text producers and are aimed to be read and comprehended by readers (Just & Carpenter, 1992). Good readers are interactive readers. They interact with texts and writers. They decode the surface information and utilize their own background knowledge in order to form comprehensive, if successfully, and correct understanding. Comprehending a text sometimes seems to be easy and effortless for readers; however, some texts are difficult to apprehend and "demands extensive storage of partial or final product in the service of complex information processing" (Just & Carpenter, 1992, p.122). When readers read, readers basically process information in which the visual information is transformed in successive processing states in forms of visual, phonological and episodic memory until the information is ultimately comprehend in readers' semantic system (Hannon, 2003; LaBerge & Samuels, 1974).

Some reading tasks could be complex. Readers use genre structures, linguistic features and other factors provided by the text producers to build up semantic system or the mental representation. In other words, when comprehending spoken or written texts, listeners or readers must quickly “retrieve some earlier presented words and phrases” (Just & Carpenter, 1992, p.122). During the comprehension process, listeners or readers retain in mind the mental representation or the themes from the previous sentences. Also they might need to generate multi-faceted propositions about what is currently read or comprehended. Readers sometimes comprehension texts literally and sometimes need to infer the implicit messages between lines. Namely, besides readers’ perception of what messages a text literally delivers, readers construct mental representations using their world knowledge and their newly-formed comprehensions about the text at hand (Duke, Pearson, Strachan & Billman, 2011). Thus, successful RC takes efforts and requires robust cognitive strength or abilities.

Instead of treating RC as a global construct, this study delves into the multi-level representational nature of RC. As Alptekin and Ercetin (2009) observe, researchers mostly consider RC to be “a global construct, paying little attention to its multilevel representational architecture and also the role played by each level in comprehension” (p.628). As mentioned above, RC of various reading tasks involves different degrees of contribution from surface coding and implicit messages (Kintsch, 1998). Due to the complexity underlying different comprehension levels, there is a need to scrutinize different levels of comprehension when it comes to investigating the relationship between WM and RC instead of treating RC as a whole. Some researchers have highlighted the need for further research to investigate the influence of L2 WM on RC in two dimensions—L2 WM on literal and inferential RCs (Alptekin & Ercetin, 2009; Jeon & Yaashita, 2014). First of all, in research concerning cognitive activities and WM, researchers mostly treat RC as a global proficiency, paying little attention to its multiple levels behind RC. Studies support a positive correlation between WM and RC but little research in this field considers different levels behind RC (Daneman & Carpenter, 1983; Jeon & Yamashita, 2014; Just & Carpenter, 1992). Thus, RC should not be regarded to be one performance or proficiency as a whole when it comes to research studying the influence of WM on RC. Secondly, the influence of WM on RC would vary with the complexity of the given texts—some texts are easy to comprehend while some texts are demanding to apprehend (Sasaki, 2000). Moreover, some texts require both literal and inferential comprehensions. It is possible that WM is involved in the multiple levels of comprehensions to different degrees; therefore, it would be reckless to acknowledge the influence of WM on RC without investigating the power of WM on different levels of RC.

The following part would be devoted to elaborating the multiple facets behind the global construct of RC from Kintsch's construction-integration model of comprehension.

Construction-Integration Model of Reading

Viewing reading comprehension as a mental representation, Kintsch (1998) suggests that reading comprehension involves at least three main levels of knowledge representations—*surface representation*, *textbase* and *situation model*. At the *surface representation*, the readers must decode the words from texts and sometimes parse them into chunks so as to grasp the grammatical relationship among the chunks. At this level of surface understanding, readers might need to understand the referential identity or the implicit causal links based on their linguistic knowledge. A text, once comprehended, becomes a system of interconnected propositions. The next level of *textbase representation* refers to the combinations of propositions across sentences.

Next at the second level of *textbase,* inside the working space of readers' WM, readers temporarily hold the propositions which are decoded from the surface representation. This level of information storage is regarded as *textbase,* and includes both global and local understanding of texts. Local comprehension refers to literal understanding about texts while global comprehension requires readers to put the literal understanding in a context of the entire texts. Both the global and local comprehensions would serve later as resources for readers to retrieve information from in order to generate a more thorough understanding. According to Kintsch (1998), fluent readers tend to retrieve information from more important propositions which have more connections among meanings of sentences (e.g., lexical decoding, word-to-text interpretation, and syntactic parsing). In other words, more competent readers are better at selecting relevant or important clues from the texts in order to comprehend the texts more correctly. On the contrary, less competent readers usually fail to select important messages and would be easily overwhelmed by too many literal messages. Hence, less competent readers usually are less able to grasp the main ideas of texts. Furthermore, readers extract meanings from sentences, gradually accumulate meanings or propositions from successive sentences and finally generate a coherent discourse understanding. Their abilities to select relevant information and to inhibit minor information are important for this level of comprehension.

Last but not least, at the next level of *situation model*, readers not only understand texts within contexts (*textbase*) but also activate their background knowledge in order to understand authors' interests or goals. *Situation model* refers to readers' global comprehension which requires readers' knowledge about linguistic elements and topics of texts. The strong connections of readers' prior knowledge, experiences, interests or goals are essential for readers to generate *situation model* successfully.

To sum up, *surface representation* is linguistic proposition; *textbase* is a symbolic and verbal structure; and the last comprehension level of *situation model* goes beyond the text (Kintsch, 1998). Like literal comprehension, the *surface representation* and *textbase* mean that readers decode the surface or literal meanings of the texts. On the other hand, *situation model*, like inferential comprehension, requires readers to understand messages beyond the surface linguistic forms. As Alptekin and Ercetin (2009) indicated, it is highly likely that the influence of WM on RC would vary in power and qualities since different reading tasks require different degrees of cognitive activation and complexities. It could be concluded that it is worth investigating RC as a multilevel representative construct when it comes to WM and RC.

Literal and Inferential Reading Comprehensions

Literal reading comprehension requires the readers to recognize or recall exactly what is stated from the original text. Inferential reading comprehension, on the other hand, demands the readers to "interpret the author's meaning through connecting information that is implicit in the text" (Dennis & Barnes, 2001, p.352). Both literal and inferential comprehensions require readers to understand and interact "with the text to different degrees" (Dennis & Barnes, 2001, p.352). However, literal comprehension is independent of higher-level processing because they differ in their underlying constructs (Hannon, 2000). In terms of complexities involved in RC, inferential reading comprehension was found to be more demanding than literal reading comprehension (Rupp et al., 2006; Sweller, 1994). Studies show that different cognitive tasks put different demands on readers' WM in terms of the intrinsic cognitive load required by each task (Gough et al., 1996; Hannon, 2000). Hannon (2000) further argues that literal and inferential comprehension exhibit weak correlation with each other because these two types of cognitive actions are actually two independent variables.

Literal reading comprehension is mostly characterized to be automatic recognition of information stated literally from texts and therefore is less demanding than inferential reading comprehension. As such, literal reading comprehension means that readers fully understand what messages authors intend to deliver. But at this level reads might not be able to generate further understanding beyond the text itself. From this perspective, literal reading comprehension is usually regarded as an inability to deeply understand texts and thus is different from inferential reading comprehension (King, 2007).

The difference between literal and inferential comprehension is clear in the exemplary sentences suggested by Duke et al., (2011):

1. Roberto desperately wanted to buy a bicycle.

2. He took an after-school job sweeping out the bodega around the corner from his family's apartment.

Literal comprehension requires readers to understand the literal message, including connecting pronouns to the antecedents. In the sentences above, successful literal comprehension means readers know the "he" in the second sentence refers to "Roberto" in the first sentence.

At the level of inferential comprehension, readers use their world knowledge or to make logical connection among the text messages. In the whole process of reading, they not only apply relevant and useful background knowledge but also have to keep in mind the mental representation of what they have read. It could be inferred that Roberto's desire for a new bicycle makes him work part-time at a bodega, a storehouse for wines or a small grocery store downtown. Furthermore, readers would infer that Roberto must be diligent and self-determined for he works for what he wants with his bare hands, because the word, bodega, reminds readers of their background knowledge about neighborhood's grocery store. In general, writers usually do not literally state the motive behind characters' actions. Instead, they expect readers to use their world knowledge or experiences to infer the personalities hidden behind characters' actions (Duke et al, 2007).

However, under certain circumstances, readers might comprehend literal messages successfully but do not make correct inferential comprehension. It would be worth scrutinizing how WM interacts with underlying facets beneath RC before it is concluded that WM has significant influence on RC. Thus, there is an urgent need to investigate the influence of WM on literal and inferential RC. All in all, instead of regarding reading comprehension as a global construct under the influence of WM, the current study is aimed at investigating the correlation between L2 WM and L2 RC in two dimensions—literal RC and inferential RC.

Working Memory Capacity (WMC)

What is WM? As it literally implies, individuals' memory is working and functioning in an active and available state in order for individuals to fluently cope with immediate cognitive tasks. It is active and not as static as short-term memory (STM[3]). Moreover, it is more than an ability to store information. Instead, Baddeley (2002) has suggested WM acts more like a cognitive skill or ability. It helps people temporarily store and process information in an efficient way in order to accomplish complex cognitive tasks, like learning, reading and reasoning. In order to understand the underlying constructs when it comes to the relationship between WM and RC, this part of literature review was mainly dedicated to the theoretical constructs of WM.

First of all, working memory has been regarded as a limited-capacity system that manipulates and stores information. It is regarded as a central component in human learning activities by cognitive neuroscientists. Scholars haven not come to an agreement about the specific definition of WM; however, there is no doubt that Baddeley's multi-component model is one of the most influential (Miyake & Shah, 1999). According to Baddeley's multi-component WM model (Baddeley, 2000, 2003), WM is a multi-component system which is composed of one supervisory attentional component (*central executive*) and three other subsystems—one processing phonological memory (*phonological loop*), anther processing visual memory (*visualspatial sketch pad*) and the other processing information related to long-term memory (*episodic buffer*). The following part included the historical background of WM, Baddeley's multi-component

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[3] STM stores individuals' moment-to-moment thoughts and perceptions and the content endures over a short term only if individuals try to rehearsal (Craik & Lockhart, 1972).

model of WM, and other renowned theories about WM.

Historical Background of Working Memory and Its Multiple Components

Historical Background

Atkinson and Shiffrin (1968) proposed the two-component model of STM and long-term memory (LTM[4]): the former served as an antechamber to a durable system that stores and processes information over a long period of time—LTM. This two-component model was unquestionable until Shallice and Warrington (1970) learned that STM performances of neuropsychological patients still remained functioning even with the damage to their medial temporal lobes which had been believed to contribute to STM. It implied that STM was not one component which simply stored information but a multileveled system with more than one storing functions. It led to the assumption, later verified and empirically tested by Baddeley and Hitch (1974), that STM was composed of three components—"one was a very efficient secretary, another a taxi driver, while a third ran a shop" (Baddeley, 2003, p. 190). They broadened the concept of verbal short-term memory by including visual and spatial temporary memory (*visuo-spatial sketchpad*), a range of control processes (*central executive*) that accounts for selection and implementation of strategies and a serial ordered verbal memory (*phonological loop*) (Logie, Osaka, & D'Esposito, 2007). The most important component, the "master system" of *central executive*, is supplemented by the other subordinating "slave systems"—*phonological loop*, *visuo-spatial sketchpad* and *episodic buffer* (Gathercole & Baddeley, 2014, p.4). Baddeley borrowed the term, master-slave system, from control engineering. It refers the WM characteristics of taking charge and maintaining information though he later discovered that the slave system of phonological loop is also capable of "providing a means of action control" (Gathercole & Baddeley, 2014, p.11)

[4] Information stored in long-term memory (LTM) is stable and remains over a long period of time. It is easily accessible with meaningful retrieval structures from short-term memory and working memory. (Ericsson & Kintsch,1995).

(See a clear diagram of WMC as a multiple-component system in Fig. 2.1).

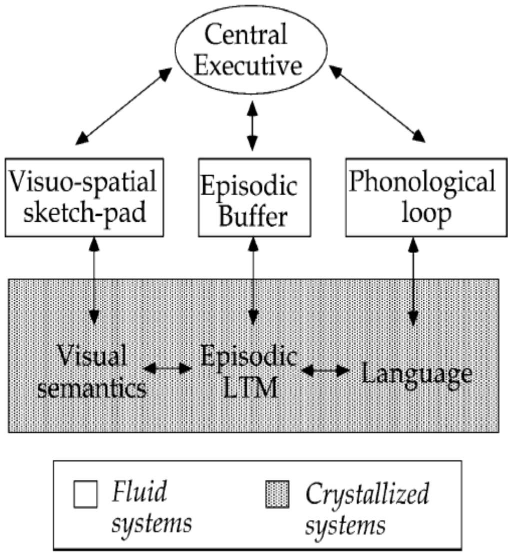

Figure 2.1. The multiple-component system of WM

Since the idea of WM came from STM, it is worth clarifying the difference between STM and WM regarding the definition and functions during the cognitive process? STM stores individuals' moment-to-moment thoughts and perceptions and the content endures over a short term only if individuals try to rehearsal (Craik & Lockhart, 1972). In comparison with STM, WM is an immediate and limited mental workspace that manipulates cognitive information which is temporarily stored. Besides it is responsible for a wide variety of complex cognitive activities, such as "verbal reasoning, comprehension, long-term leaning" along with language learning and reading (Baddeley, 2003; Baddeley, 2007, p.5). While WM stores and processes information through sensory stimuli from reading texts for instance, it mediates among perceptions, LTM and actions. The process of mediation involves retrieving relevant information from LTM (Baddeley, 2012). The information undergoing manipulation in WM will be either forgotten or stored inside LTM (Rai et. at, 2011). The active process in WM takes place mainly in the prefrontal context and could be influenced by emotional context, such as anxiety (Gray, Braver, & Raichle, 2002). More importantly, WM is limited by individuals' different capacity and the process time of completing cognitive tasks.

Unlike STM, which passively stores information, WM not only stores but also actively makes connection between the current information and old knowledge from LTM while individuals strive to apprehend ~~the~~ cognitive tasks on a grand scale (Jerman, Reynolds, & Swanson, 2012). Readers connect what they know from current texts to any relevant information they have already known. At the same time readers move toward the goal of comprehending the reading tasks at hand effectively. As Baddeley suggests (2012), when it comes to the function of multi-component working memory model, STM could be regarded as "a simple storage of information, contrast to long-term memory" (Baddely, 2012, p.4). Namely, STM stores immediate information, WM-actively delegates necessary information, new or old, and relevant background knowledge from LTM in order to understand reading tasks.

Recent evidences suggest that WM goes beyond the function of information storage (Baddeley, 2012). Children in a study by a renowned Russian psychologist Alexander Luria on investigating kids' learning process were found to gradually learn independently by combining their background knowledge and new information from new texts when they were fully engaged. In this case, children demonstrate progress in learning for they held new information temporarily and made meaningful connection to background knowledge. The importance of executive attention and the dual function of WM were emphasized in that study. The information stored in the slave systems of WM lasts for a short period of time, "unless constantly rehearsed" or delegated in task performance under the control of *central executive* (Jerman, Reynolds & Swanson, 2012, p.144). It suggests that successful cognitive tasks require not only the temporary storage of current information but also the function of the central executive to manipulate the task-relevant information so as to accomplish complex cognitive tasks.

Phonological Loop

These three slave systems all have their own specialized missions in order to help individuals temporarily store and process information. One of the components, p*honological loop*, is a temporal verbal-acoustic storage system which is in charge of immediate retention of sequences of digits, or "verbally coded information" (Gathercole & Baddeley, 2014, p.4). It "comprises a brief store with a means of gathering information by vocal and subvocal rehearsal" (Baddeley, 2012, p.7). Factors, such as word length, irrelevant sound effect and verbal suppression, would influence how people remember information by using sound clues. To prove the significance of *phonological loop* in learning, Adams and Cathercole (1995) compared the recall of nonwords—*loddenapish* and *contramponist*. The latter nonword had similar word structures and sounds in comparison with the former one. It turned out that learners could remembered the word, *contramponist*, better since the underlying English structure of words were matched to learners' prior knowledge about English words. The results showed that WM plays an important part in vocabulary acquisition with resources from the knowledge in LTM.

In terms of reading comprehension, awareness of phonological structures in words is a primitive predictor of word recognition performance (Bishop & Adams, 1990; Deavers & Brown, 1997). If readers' *pholonogical loop* in WM functions well, readers would have sufficient knowledge about the relationship between graphemes and phonemes, which greatly helps reader to understand texts better. Also the ability to fluently recognize words alleviates readers' cognitive loads, which spares more cognitive space in WMC for further demanding cognitive activities. Hence, Rapala and Brady (1990) suggests that high-level cognitive tasks would be difficult if readers fail to have ideal control of phonological processing.

Taken together, the function of *phonological loop* enables readers to read fluently and correctly, which makes *phonological loop* important and essential for reading comprehension and other cognitive tasks.

Visuo-spatial Sketchpad

On the other hand, *visuo-spatial sketchpad* is viewed as a parallel visual subsystem to *phonological loop* which mainly maintains and manipulates spatial or visual information. Readers recall items or messages easily if they could recall the specific location in the source text—human brains remember things using clues of sounds, visual and spatial clues printed in paper for example. In vocabulary learning, children learn words faster if visual clues of words are provided. Baddeley (2012) indicated that duration of word recall was facilitated with visual aids.

Central Executive

Last but not least, all the cognitive behaviors and processes are controlled by *central executive.* It is regarded as "a purely attentional system" and also the most important component in WM (Baddeley, 2012, p. 14). C*entral executive* functions as a shop owner or a company CEO that actively and automatically makes decisions and performs functions under human sub-consciousness (Baddeley, 2001, 2003, 2012). Individual receive new information through sensory system—hearing, seeing, and reading. The understanding of cognitive tasks at hand requires the relevant and helpful knowledge from LTM. Individuals generate thorough understanding by integrating old and new information, and *central executive* is greatly responsible for this process of information manipulation (Baddeley, 1996). Besides the function of controlling information, *central executive* is also responsible for inhibition which is essential for successful RC. Inhibition refers to the ability to select relevant information and ignore the irrelevant messages. When individuals deal with overwhelming information from complex cognitive tasks, such as inferential comprehension, their ability to inhibit irrelevant information is quite important (Kane et al., 2001). Simply put, *central executive* is responsible for coordinating other WM components and is also in charge of controlling information. The efficiency of *central executive* and the demands or abstractions vary inversely. Because

WM is a limited-capacity system, demands from each cognitive task would compete for mental space in WMC with WM efficiency. Thus the more demanding the current tasks are, the less efficient WM would be.

Episodic Buffer

Later in a case of an amnesic patient, Baddeley (2000) introduced the last and fourth component, *episodic buffer*, which plays the role of “binding together information from a number of different sources into chunks or episodes” and served as a buffer to “combine information from different modalities into a single multi-faceted code” (Baddeley, 2003, pp. 191-203) (See fig. 1 for WM as a four-component system). *Episodic buffer* is able to convert received stimuli into meaningful chunks meaningfully and creatively. This binding function allows readers to imagine something new, such as an “ice-hockey-playing elephant” and recall new information easily (Baddeley, 2012, p.16). Also it consumes less cognitive space in WMC without excessive focus on linguistic messages, which makes the integration of information work more smoothly in WM. Collectively, visual, phonological and semantic information is integrated by *central executive* in the workspace of *episodic buffer*. *Episodic buffer* can be viewed as a buffer, or a booster station, between LTM and *central executive* (Baddeley, 2000, 2003).

Theories Concerning WM and Reading Comprehension

Working Memory and Attention—Engle and Cowan's Model

Engle and his colleagues suggest that difference in individuals' WMC is mainly about their ability to control their own attention to the tasks, rather than how much information ones can store in mind (Engle, Tuholski, Laughlin, & Conway, 1999). Readers' attentional control refers to the ability to focus attention on task-relevant information so as to shift information between different levels of mental activities (Engle & Kane, 2004). Besides the ability to focus attention, Engle and Cowan emphasize the importance of the ability to inhibit irrelevant information. Inhibition means the ability to ignore irrelevant interference, including information from the tasks at hand or other possible disturbance, such as fatigue. If inhibition functions well, individuals would be able to successfully withdraw relevant information or background knowledge from LTM and neglect distractions. From this perspective, WM is more like the efficiency or the ability to execute attention, rather than the ability to maintain or remember information for a short period of time (Kane et al., 2001).

Studies have indicated that these two elements in WM (abilities to focus attention and to inhibit distraction) are more important than readers' space or capacity of temporarily holding memory (Engle, 1996, 2002; Engle et al., 1999; Kane et al., 2001). In other words, WM is regarded as a multi-component system that actively holds information when individuals process immediate information along with possible distractions (Kane, 2005). To understand a text correctly, readers must focus on immediate information consciously and attentively and inhibit irrelevant messages. By doing so, they would be able to formulate mental representation of the very text correctly.

This theory has experimental supports. Studies have shown that persons with higher WMC (working memory capacity) are better at controlling their attention in comparison with those with lower WMC (Kane et al., 2001). Some possible distractions might not come from the outside environment but from the cognitive activities or the texts themselves. When individuals find what they comprehend from the former text against what they understand in the later text, those with high WMC would eliminate the irrelevant information and move on searching for other useful or coherent clues. Those with higher WMC can more successfully and automatically resist interference of all kinds under normal situations. Having better function of inhibition over information enables readers with high WMC to process information more efficiently and more successfully. However, those with low WMC might either not be able to discriminate irrelevant information or overwhelm themselves with minor information. Eventually, without inhibition, readers with low WMC would comprehend texts less ideally than those with high WMC.

Working Memory and Long-term Memory—Ericsson and Kintsch's Model

Though the literature has emphasized the importance of WM in terms of RC, there is doubt about how some demanding cognitive activities, such as inferential RC, can be processed within limited space storage (Ericsson & Kintsch, 1995).

WM functions like an active mental workspace to process and synthesize information when individuals encounter cognitive tasks. Though the influence of WM sounds invincible, it has its own limitation—a rather limited cognitive space. Thus adequate space is necessary for demanding tasks. WMC could support in dealing with cognitive tasks only if the space is not consumed excessively. To compensate the restriction, according to Ericsson and Kintsch (1995), background knowledge from LTM is essential. WM could be expanded with resources from background knowledge from individuals' LTM (Ericsson & Kintsch, 1995).

Baddeley (2002) focuses on interaction between tasks at hand and the four WM components. On the other hand, Ericsson and Kintsch (1995) focus on the interaction of WM and LTM when it comes to understanding texts at hand. The predictive power of WMC on cognitive tasks not only depends on the short-term working interface of storing and processing information but also relies on the resources from individuals' background knowledge of LTM (Ericsson & Kintsch, 1995). As mentioned above, while WM stores and processes incoming information through sensory stimuli, from reading texts for instance, it mediates among perception, LTM and actions, which includes retrieving relevant information from LTM and depends on retrieval structures in memory system (Baddeley, 2012).

The retrieval structure, a stable structure in memory, enables readers to link their knowledge to the immediate information at hand. The information, like propositions from reading, would become cues. Those cues are available items in WM that could activate or stimulate memory inside LTM. When individuals have robust retrieval structures, individuals would be more capable of facing demands of complex cognitive tasks like experts, making successful reading inference for example. According to studies, retrieval structures, which support participants' performance of cognitive tasks and its relationship with WMC, come after some prerequisites (Chase & Ericsson, 1982; Ericsson & Kintsch, 1995). The first prerequisite is that a large body of knowledge and problem-solving pattern concerning the undergoing information is required. The second prerequisite is that individuals must be able to anticipate or be prepared for the coming demands for information retrieval via recognizing the tasks. Recognizing the tasks and knowing the types of cognitive thinking pattern might help individuals comprehend and solve the tasks efficiently. Last but not least, the third prerequisite is that individuals must have his or her own encoding strategies, developed through continuous practices, so as to fluently retrieve information from LTM and store selective information from tasks at hand into LTM.

Ericsson and Kintsch (1995) suggest that WMC has great influence on RC and so is background knowledge of domain field. Likewise, Brown and Hulme (1992) point out that L2 readers' comprehension would be improved when they have adequate background knowledge about the language or the text content. When individuals are involved in L2 input, their L2 WMC tends to be reduced in comparison with their L1 WMC. The reduction of their WMC is caused by the lack of adequate LTM contributions to L2 WMC. It implies that LTM fuels the work efficiency of WM. Knowledge in domain field is stored in an organized structure in LTM. This organized structure of domain knowledge makes it highly accessible when readers withdraw relevant knowledge to support their comprehension. Namely, while the relevant knowledge is stored in LTM, LTM would be more accessible and supportive to RC and other cognitive activities (Ericsson & Kintsch, 1995). In brief, three elements are mutually beneficial—WM, LTM and RC.

Capacity Constrained Comprehension Theory and Working Memory—Just and Carpenter's Model

Though WM plays an important role in language comprehension as mentioned above, it has its own constrains. Daneman and Carpenter (1980) have suggested that WM has stronger relationship with high-order cognitive activities, such as language comprehension, reasoning, and problem solving, rather than with simple cognitive tasks. During the process of comprehension or cognitive activities, WM can be viewed as a "pool of operational resources that perform the symbolic computations and thereby generate the intermediate and final products" (Daneman & Carpenter, 1980, p.122). Listeners or readers, according to Just and Carpenter (1992), will "construct and integrate" ideas from the spoken or written discourse (p.122). During this process, listeners or readers interpret the immediate information and temporarily store it as a meaningful mental representation—WM plays a crucial role in storing and processing information. Furthermore, according to Just and Carpenter's WMC theory, comprehension performance "declines with an intrinsic memory load beyond one's capacity, such as retaining information across successive sentences of a text, or an extrinsic burden" (Just & Carpenter, 1992, p.135). And the decline is even more severe for low-span readers. Due to the capacity limitation, readers with low WMC need to have more reading time to process overwhelming information and are more likely to make wrong comprehension. Readers with high WMC, on the other hand, might also have poor comprehension even if they have higher WMC. For readers with high WMC, reading skills, such as skills to select useful clues, are important—their WMC would be consumed extremely when readers tend to interpret sentences from multiple angles and to generate more than one syntactic ambiguity. Briefly speaking, based on Just and Carpenter's WMC capacity theory (1980), how readers comprehend a text depends on their WMC. When the tasks at hand exceed or overload readers' WMC, "the storage and computation" functions of WM would decline (Just & Carpenter, 1980, p.124).

To briefly summarize these theories mentioned above, WM is responsible for temporarily storing and processing information, which makes WM essential for a wide range of complicated cognitive activities. Some (Daneman & Carpenter, 1980) propose that each individual has limited WMC while some other scholars (Anderson, 1983) define that WM is not necessarily limited in capacity. Responding to both different perspectives, Baddeley (2002) suggests in his latest review on working memory that WM should be regarded as a theoretical "framework for the analysis of the contribution of working memory to languages" (Baddeley & Hitch 1974; Baddeley 2002; Gathercole & Baddeley, 2014, p.2).

Despite the nuance of differences among WM theories and different opinions on its influence on cognitive activities, the researchers mentioned above all share the idea that WM helps store and process information. Also, with WM, individuals would be more able to focus and switch attention when dealing with immediate cognitive tasks—either to make comprehension or to discard irrelevant information (Baddeley, 2007; Engle, 2002). It is generally agreed that during the working process in WM, knowledge from LTM (e.g., grammar knowledge, vocabulary knowledge, phonological knowledge) will be retrieved and withdrawn into an active mental workspace. Without WM, RC is impossible (Jeon and Yamashita, 2014). Briefly speaking, WM definitely influences the quality of cognitive tasks regardless of the differences among WM theories.

WM and RC—L1 and L2

Though Fodor (1986) commented on the WM model of Baddelely that WM was "unhelpful and neuropsychological implausible" (Baddeley, 2012, p.7), WM is still influential on cognitive tasks, like RC (Alptekin & Ercetin, 2011; Nassaji, 2002; Kane, Bleckley, Conway, & Engle, 2001; Unsworth & Engle, 2007). Responding to this, Baddely admitted the incompletion of his model and urged others to complete his WM theory with more studies. Instead of focusing on flaws of his WM theory, Baddeley (2012) suggested that researchers should consider WM as “a relatively loose theoretical framework rather than a precise model that allows specific prediction” (p.7). Even though the WM model is not concrete and specific, Baddeley (2012) suggests that c*entral executive* should play an important role of information manipulation when it comes to cognitive activities and WM. When more than one tasks or cognitive activities are required to be processed, the resources or space would be compromised under the competition among the needs to deal with tasks at hand. In the long run, it increases the burden on *central executive* and slows down the efficiency to complete the immediate task. Due to this, it makes WMC related to cognitive tasks and the efficiency of accomplishing them.

WM is highly related to RC basically because WM helps maintain immediate information in mind. More importantly, WM enables readers to construct meanings from multifaceted resources under conditions of full engagement (Tierney, 1990). In terms of engagement, one important construct of WM is the automatic operation of *inhibition*, which controls the content or mental representation of WM by preventing irrelevant stimuli from overloading WM capacity (Borella & De Beni, 2008; Engle, 2001; Kramer, Humphrey, Larish, & Logan, 1994; Rosen & Engle, 1998). From this perspective, it is clearly that both RC and operation of WMC tap the same construct, which explains the high correlation between the two shown in numerous studies. Also, Daneman and Carpenter (1980) found that the result from RSTs, individuals’ WMC (working memory capacity), is able to predict participants’ prose comprehension skills in their college participants. They continued to find more details of the ways which WMC seemed to underpin components of WMC, such as the ability to make inference and to extrapolate beyond the given literal information.

Furthermore, Just and Carpenter (1992) noted that the dual functions of storage and process in WM make humans capable of conducting various linguistic (speech, sound, and visuo-spatial) and conceptual tasks (semantic and episodic information) smoothly and automatically. During the automatic cognitive process, comprehending a text for instance, relevant information from LTM is retrieved and would be combined with the dynamic newly-received information in WM so as to establish a meaningful mental representation as a whole (Alptekin & Ercetin, 2009; Daneman & Carpenter, 1983; Daneman & Merikle, 1996; Walter, 2004). And this automatic cognitive process makes WM relevant to RC performances.

When it comes to L1 or L2 in terms of WM and RC, studies show that L2 RC is more relevant to L2 WM than to L1 WM (Daneman & Hannon, 2007). It is suggested that cognitive resources underlying L1, L2 and even L3 are closely related to each other. L1 WMC is found to be strongly or moderately correlated to L2 WM capacity. The correlation was both over .70, which suggests a strong relation force (Osaka & Osaka, 1992; Osaka, Osaka & Groner, 1993). Other studies found a moderate correlation between L1 and L2 WM capacity ranging from .39 to .68. That led to the burgeoning studies concerning the relationship between WM and L1/L2 RC for that WM is said to be a good predictor of RC and scant studies investigate the cross-language interplay of WMC and comprehension (Danemen & Carpenter, 1980; Harrington & Sawyer, 1992). As indicated in several studies, L2 WM capacity is strongly correlated to L2 RC rather than L1 WM capacity to L2 RC (Chun &Payne, 2004; Walter, 2004; Miyake & Friedman, 1998). Hence this paper is aimed at studying English as L2 RC under the influence of L2 WMC.

Measurement for WMC—Reading Span Test (RST)

Individuals' WMC is usually measured with a dual-task which requires participants to complete both processing and storage tasks. Span tasks for measuring WMC usually “include a dual-task paradigm which combines a memory span measure with a concurrent processing task” (Alptekin & Ercetin, 2010, p.206). Dual-tasks are designed to measure the two functions of WMC—to temporarily store and process information at the same time. It comes in a variety of types, such as operating span, counting span, and reading span. The WM theory emphasizes the *functional importance* of “an immediate-memory system that could briefly stores a limited amount of information in the service of ongoing mental activities” (Conway et al., 2005, p.769). The design of dual-tasks could assess individuals’ ability to store and process information at the same time. In comparison with other span tasks which do not include readings in procedure, a RST, according to research would have better validity and reliability when it comes to the relationship between WMC and RC (Conway, et al., 2005; Friedman & Miyake, 2004).

What is a dual-task precisely? In completing a RST, participants need to complete two tasks simultaneously. According to Conway et al. (2005), the WM system would fail to demonstrate its function fully if it is encountered with one single task of simply storing information or rehearsing factual information. Instead of one single task, dual-tasks or complex tasks have been developed to measure WMC and the efficiency of *central executive* inside WMC. Complex tasks demonstrate to-be-remembered stimuli, such as letters or numbers, and those stimuli are spread between interfering components, such as reading sentences (Daneman& Carpenter, 1980) or problems to solve (Turner & Engle, 1989). Complex tasks are to measure WMC and are more related to high order cognitive tasks, such as making reading inference (McCabe et al., 2010; Unsworthy & Brewer, 2009). Regarding the trade-off between processing and storage as interdependent components operating inside WM, the tasks are assumed to show that “increase in the amount of processing demands leads to a decrease in the number of storage items and vice versa” (Alptekin & Ercetin, 2010, p.206).

The literature has emphasized the importance of WM when it comes to its influence on RC; however, there is little consensus on the measurements and assessments of WM- (Friedman & Miyake, 2004; Juffs, 2004; Waters & Caplan, 1996). Difference WMC tasks have different procedures or tasks (Waters & Caplan, 1996). For instance, a recall-RST requires readers to judge the grammaticality of sentences and write down cues afterwards (Harrington & Sawyer, 1992; Walter, 2004). A cognition-RST requires readers also to judge the grammaticality of sentences but to identify ending words of sentences from a list of provided options.

A recognition-RST measures the participants' abilities to recognize the ending words from the provided options or "externally presented retrieval cues" (Unsworth & Engle, 2007, p.112). Unsworth and Engle (2007) suggest that performances in recognition-RST are mainly driven by two independent mechanisms: fast-pacing and automatic process of recognition based on familiarity. Likewise, Alptekin and Ercetin (2009) pointed out that the performance of recognition-RSTs could be "partially contingent on a strategically controlled search process of long-term working memory or on the automatic retrieval of information from long-term working memory" (p.635). During the process of completing a recognition-RST, participants can quickly target ending words from externally presented cues, which is called the automatic process of recognizing words. It operates based on participants' recognition of familiarity or words which they have read from the RST. In the dual-task of grammaticality judgment in recognition-RST participants need to respond to externally presented retrieval cues. The provided list of sentences or the multiple-choice questions provide participants with the chance to retrieve relevant information from their long-term working memory by recognizing cues automatically.

However, when completing a recall-RST, participants remember the ending words from memory, which resembles free-recall tasks. To complete a recall-RST, the participants recall their memory of ending words from their internally generated cues. Short-term working memory is activated in the controlled search process inside long-term working memory. Instead of automatically recognizing words, participants internally generate retrieval cues by using relevant cues to the presented ending words with knowledge from their long-term working memory. Altepkin and Ercetin (2009) suggest that there is a qualitative difference between recall-RSTs and recognition-RSTs in terms of their different cognitive constructs. A recall-RST requires the participants' abilities to inhibit irrelevant information and to focus on relevant information in order to retrieve items using internally generated cues. Thus, free-recall tasks or recall-RSTs would be more demanding than recognition-RSTs and the cognitive demands posed by these two different RST types on individuals should be different. It is expected to see the influence of WM on RC vary when WMC is measured with these two RST types.

Regardless of RST types, researchers proposed that WM span tasks of all kinds all account for similar or the same variance in comprehension (Turner and Engle, 1989). However, Chun and Payne (2004) found no significant correlation between WMC and RC when using recognition-RSTs in their research. According to Chun and Payne (2004), the cognitive tasks in recognition-RST in which readers recognize correct options of ending words from RST do not correspond to the construct behind RC. To investigate the relationship between WM and RC, studies should consider the factors of different WMC tasks and dimensions of RC (Chun & Payne, 2004). That is, different amounts and types of working memory cognitive resources involved in different cognitive tasks is usually not taken into consideration in studies (Alptekin & Ercetin, 2009). Given the scant consensus concerning which RST is better to measure WM, the investigator was interested to find out whether the influence of WM on RC would vary when WM is measured with a recall-RST and a recognition-RST. To sum up, this paper was aimed to find out the relationship between L2WM of English learners in high school and their abilities to make literal and inferential comprehensions.

CHAPTER THREE

METHODOLOGY

Participants

The participants in this study were 190 students from 7 classes in a Chiayi City Junior High School with a total of 37 classes. The participants ranged from 8th graders to 9th graders (aging from 12 to 15 years old). They had learned English since 1st or 3rd grade in elementary school (for about seven to nine years). These 190 students in the current study did not have similar language proficiency. There were some obstacles for the feasibility of the study. First of all, under the restriction of course schedules at school, it was unlikely to withdraw students of the same language proficiency from my school, which would have stopped them from attending their scheduled classes. In order to include as many participants as possible in the research, I asked as many classes as possible to participate in the study and only the teachers of these 7 classes agreed to spare some periods for conducting this experiment in class. Secondly, the number of students passing the GEPT elementary level in the researcher's school was not many—there were about 30. If the participants were only those 30 students passing the GEPT elementary level, the number of participants would be too few and would sabotage the power of analytic generalization. Thus, the study included these 190 students from the 7 classes and the number of participants was appropriate for analytic generalization. Therefore this convenience sample of 190 students from 7 classes was finally invited as participants. Although the language proficiency among the participants varied in levels, the individual difference was statistically canceled among one another under the number of 190. Also Chinese counterparts for some difficult English words were provided in the RC test in order to avoid the reading difficulty from unknown words.

As for the grouping criteria (recall-RST and recognition-RST), due to the limitation of course schedules at school, participants had to attend their own classes. The investigator decided to group entire classes into same WM group in order to carry out the study. Thus, no specific grouping criterion was applied—the participants from three classes accomplished a recognition-RST and a RC test; the participants from the rest accomplished a recall-RST and a RC test. The test of RC contained four passages with five literal and five inferential RC questions, and was designed to assess participants' ability to read literally and inferentially.

Instruments

The instruments of this study included (a) recall- and recognition-reading span test (RST) to measure working memory capacity (WMC); (b) a RC test with literal and inferential comprehension questions. Each participant completed the whole procedure in the following order: a WMC RST and a RC test. 104 participants took a recall-RST and a test of RC; the other 86 participants took a recognition-RST and a test of RC. The RST was administered in one class period of their English class in the classroom and the RC test was done in another period.

Reading Span Task (RST)—Measurement of Working Memory Capacity (WMC)

The reading span task (RST) or a working memory test developed by Daneman and Carpenter (1980) is the most commonly used tool for WMC. Other span tasks for WM include operation span and counting span. Among all types of WM tools, RSTs are found to be highly related to RC. Daneman and Carpenter (1980) define RSTs as dual-tasks that require participants to complete two simultaneous missions. RSTs require participants to "fulfill both processing and storage requirement" simultaneously (Conway et al., 2005, p.581). Namely, two tasks have to be done by the participants simultaneously: to read a series of sentences and to recall or recognize the final words later on. Participants' WMCs were the maximum number of ending words that he or she recalled or recognized from multiple-choice options.

A RST adopted from the study of Harrington and Sawyer (1992) was administered in the current study. The RST consisted of 42 unrelated sentences with 21 grammatical sentences and 21 ungrammatical sentences. All 42 sentences were randomly assigned into three trials. Each trial had 2 sentences, 3 sentences, 4 sentences and 5 sentences; the number of sentences in each trial was increasing from 2 to 5. There were 42 sentences in total. Every sentence ended with different words. Conway and his colleagues (2005) indicate that the item/sentence number of "two to five or six" was sufficient to test WMC span in order to "create the potential for *ceiling effects* among those participants in the upper end of the performance distribution" (p.773). The adopted list of 42 sentences was shown in the Appendix A. A brief summary of relevant literature about RST was in Table 3.1 below and a sample test of RST was in Table 3.2 in the following.

Table 3.1 Summary of Literature Review on RST

Daneman and Carpenter (1980)	1. RST, a dual-task, could better assess the influence of WMC on RC. 2. RST is able to predict participants' prose comprehension skills.
Friedman, & Miyake (2005)	The dual-task design of RST requires participants to complete two sub-tasks simultaneously: one is to store information and the other is to process it.
Alptekin & Ercetin (2011)	The sub-task of information storage in RST requires participants to memorize the ending words of sentences or to recognize them. The other sub-task of information process requires the participants to judge the grammaticality.

Table 3.2 Example Sentences of RST with WMC=3

trial 1	All morning the two children sat and talked under a tree. *He played baseball all day at the park and sore got a arm. At night the prisoners escaped through a hole in the wall.
trial 2	*His younger brother played guitar a rock and roll in band. The people in northern Europe always like to travel by train. *The last thing he did was take to a nice hot bath.
trial 3	The clerk in the department store put the presents in a bag. *I saw a child and her father the river near playing ball. *Suddenly the taxi opened its the door in front of bank.

These 42 sentences, each of which consists of 11-13 words, were all simple sentences in active voice, not passive voice. The sentences were 3 to 4 words shorter and syntactically simpler than the sentences in the RST used by Daneman and Carpenter (1980). Harrington and Sawyer (1992) suggested that sentences of RSTs be shorter in order to avoid the possible "*floor effect*" (p.28). *Floor effect* refers to extremely low scores for individual participants because of task difficulty in studies. Therefore, true WMC span for each one can be measured (Harrington & Sawyer, 1992). Besides, each of the 42 sentences ended with different words, and the ending words were designed to "avoid phonologically similar words in the same set" (Harrington & Sawyer 1992, p.28). For instance, minimal pairs of *ball* and *fall*, and *around* and *ground* were not included in the same set. In terms of grammaticality, the grammatical sentences were correct in terms of semantic and syntactic sense while the ungrammatical sentences were designed by reversing the last four to six words of grammatically correct sentences. According to Harrington and Sawyer (1992), syntactic accuracy is considered as an intruder into participants' storing performance and it can also prevent participants from merely memorizing the ending words without truly understanding the sentences. For example, grammatical sentences are like "*The clerk in the department store put the present in a bag.*" By reversing the last four to six words, ungrammatical sentences are like "**The last thing she did drink a was to hot cup of tea"* (Harrington & Sawyer 1992, p.29).[5]

These 42 sentences came in three trials (see exemplary RST trials in Table 3.2). All the three trials had sentences of 2, 3, 4 and 5 increasing in the number of the sentences (see Appendix A for all the 42 sentences). The participants took the RST independently and were informed beforehand to expect the increasing number of sentences. Each sentence was displayed on one slide and shown only once. Every sentence was shown on one PowerPoint slide for 10 seconds. Blank slides were inserted in slides to separate sets of 2, 3, 4, and 5 sentences. When seeing the blank slides, the participants wrote down the ending words they remembered or selected the ending words they remembered.

Meanwhile, each participant was asked to judge the grammaticality of sentences while they read the sentences. They read and wrote down their judgment on answer sheets. Grammatical judgment used here "grammatically represents the processing measurement of their reading span" (Alptekin & Ercetin 2011, p.249). During the presentation of the sentences, participants read, processed, and judged the grammaticality. Right after they saw the blank sheet at the end of each set, they needed to recall or recognize the final words in the same order of the presentation. To recall, the participants wrote down the ending words. As for the recognition-RST, participants judged the grammaticality when they read them. The answer sheet for the recognition-RST was a multiple-choice test, and four options were provided for each ending word of sentences. The participants chose the ending words after 2 sentences, 3 sentences, 4 sentences and 5 sentences. There was a warm-up practice of three sentences demonstrated in the same way of the later RST for

[5]Examples of un/grammatical sentences with syntactic accuracy as intruders into WM storage are "*He looked across the room and saw a person holding a gun*" and "**The girl picked up her bag and down to went the gym*(Alptekin & Ercetin, 2011, p.249)"

the participants at the very beginning of answering the RST. The participants could understand how to complete the RST by doing the warm-up practice.

As far as the scoring methods of RST are concerned, two out of four commonly used methods (e.g., total words, proportion words, correct sets words, and truncated span) were discussed and testified to have satisfactory reliability and validity—total words and proportion words. There were three trials of sentence sets in the RST. The number of sentences in one set was increasing as the RST proceeded. To be specific, in the first trial the participants read one set of 2 sentences, 3 sentences, 4 sentences and 5 sentences. In the second trial, the participants also read one set of 2 sentences, 3 sentences, 4 sentences and 5 sentences. In the last trial, the participants also read one set of 2 sentences, 3 sentences, 4 sentences and 5 sentences. There were 42 sentences in total. With the first method of total words, participants' WMC refers to the total words they remembered from all the three trials. For instance, when a participant successfully remembered two out of five words on a trial in a recall-RST or recognized two out of five words on a trial from the provided list in a recognition-RST, his or her WMC was two. 42 sentences meant 42 ending words, and the maximum points for one's WMC was 42.With the second method of proportion words, the participants' WMC would be able to reach the average percentage of correctly recalled or recognized words across the number of words in all trials. For example, if the participants remember two out of five words in one trial, the WMC for him or her was .4 (40%). And all the correctness percentage across all the trials was averaged as that participants' WMC. With this scoring method, failure to recall words at beginning part of a RST, two sentences in one set for example, would result in lower scores than at later level, five sentences in one set for example. With this scoring method, the maximum scores under this proportion method would be 1.00. As Conwey et al. (2005) indicated the two methods of total words and proportion words present a normal distribution, good reliability, and reasonably higher correlation with RC performances. Friedman and Miyake (2005) suggest the total number of correctly recalled (or recognized) words across be the better scoring method because it has better reliability and is able to demonstrate stable correlation with RC.

Afterwards, a Cronbach's alpha test was employed to ensure the internal consistence of reliability in this psychometric test. In other words, Cronbach's alpha helped ensure that the result truly represents every individual participant's WMC. Although every participant had their own particular strategies of conducting the RST developed during the test-taking process. The Cronbach's alpha suggested the RST used in this study have satisfactory reliability. The Cronbach's alpha was 0.663 for the RST and 0.781 for the RST in the pilot study, which fell within the acceptable range of scores being higher than 0.5. Furthermore, the interview with the participants also supported the construct validity of RSTs in terms of testing WMC. WMC is composed of three main components—*phonological loop*, *visuals spatial sketchpad*, and *central executive* interacting with episodic long-term memory (LTM), visual semantics and languages. In order to memorize the ending words during the RST in this study, some participants used the clues of sounds of the ending words to memorize while some linked the meanings of the ending words into a meaningful sentence or a visual picture. Still some used both sound and semantic clues to keep the ending words in mind. The three main techniques used to memorize the ending words is consistent with the WMC components—*phonological loop, visual spatial sketchpad, episodic buffer*— and visual semantics. Therefore, the construct validity and reliability of the RST was guarded and applicable.

Two Versions of RST—Recall-RST and Recognition-RST

In this study I used a recall-RST and a recognition-RST to investigate whether the influence of WM on RC differed when WM was tested with different RST types. The first task of reading 42 sentences in a recall-RST and a recognition-RST were the same, but the second task of memorizing the ending words was different. On the test of a recall-RST, participants remembered the ending words while judging the grammaticality of sentences. At the end of each set, participants were asked to spell out and write down the ending words. On the other hand in recognition-RST, participants also remembered words and did grammaticality judgment tasks. But at the end of each set, participants in the recognition-RST group did not have to write down words but to select the ending words from a provided of four options for each sentence. The options in the recognition-RST included three distracters and one correct ending word. Distracters were nouns from the same semantic category or ending words of each sentence.

There would be a qualitative difference between recall-RSTs and recognition-RSTs regarding the cognitive operation which both types of RSTs require (Altepkin & Ercetin, 2009). To complete the recognition-RST, participants recognized the grammaticality of given sentences and the ending word of each sentence from a set of lexical options. In other words, in the dual-task of grammaticality judgment in recognition-RST, participants responded to externally presented retrieval cues. The provided list of sentences or the multiple-choice questions offered participants with the chance to retrieve relevant information from their long-term working memory.

However, when completing a recall-RST, participants remembered the ending words from memory, which resembled to free-recall tasks. During the process, participants internally generated retrieval cues. To generate retrieval cues activated participants' background knowledge in their long-term working memory. Free-recall tasks or recall-RSTs is more demanding than recognition-RST; the ability to retrieve item using internally generated cues works well when participants were able to delimit the cognitive search process focusing on relevant information. In contrast, the provided options in multiple-choice questions of the recognition-RST functioned as external cues. To complete it, participants had to generate cues internally. Though the difference among applied RSTs has usually been overlooked in studies, the underlying cognitions of these two RSTs are distinct functionally. The recognition-RST measures the participants' abilities to recognize the ending words from the provided options or "externally presented retrieval cues" (Unsworth & Engle, 2007, p.112). On the other hand, when taking the recall-RST, the participants recall the stored item, the ending words, from their internally generated cues. To be specific, the WMC of these two RSTs might reflect different cognitive processes. Since WMC is concerned with the mental strength or cognitive efficiency, the more cognitive-demanding a RST was hypothesized to better demonstrate the influence of WMC on RC than the other.

A Reading Comprehension Test Adopted From CAP

A reading comprehension test focusing on literal and inferential comprehension was designed to measure participants' abilities to identify facts directly stated in texts and to grasp the implicit meanings for texts. This test consisted of 4 reading passages with a total of 5 literal comprehension and 5 literal comprehension questions. Each passage had two to three comprehension questions. The questions were multiple choice questions (four alternatives per question). Every raw score for each participant was calculated based on the number of questions they had correct answers for. Each correct answer for each question was scored with 1 point. The maximum score of a reading test was 10 points. Non-academic passages were chosen and therefore participants' comprehension was not interfered from difficult lexical items.

In order to ensure satisfactory validity and reliability of reading tests, the comprehension test used in this study was adopted from the English test of CAP (Comprehensive Assessment Program for Junior High School Students) in 2014. Chinese counterparts were not included in the formal exam of CAP in 20014 since the test-takers of CAP are all 9th graders who had completed the entire high school English course. But in this study necessary Chinese counterparts for English vocabulary were provided and listed nearby since the participants of the current study ranged from 8th to 9th graders. Vocabulary knowledge is essential for reading comprehension in that "vocabulary knowledge is fundamental to reading comprehension; one cannot understand text without knowing most of the words mean" (Nagy, 1988, p. 9). Possible reading difficulty resulting from unknown vocabulary would be avoided.

Reading Comprehension—Literal and Inferential Comprehension

The RC test was a test of multiple-choice questions. 10 questions in total were included—5 literal RC questions and another 5 inferential ones. The classification standard was adopted from Pearson and Johnson's taxonomy of RC questions (see Table 3.3 for the taxonomy of literal/inferential reading; Scales & Shen, 2004). The 5 literal questions of the test were textually explicit; the other 5 inferential questions were scriptally implicit and scriptally implicit. The literal questions required participants to understand texts based on explicitly stated clues of the texts and facts, while the inferential questions required the reading ability to bridge and fill the gap of mental representation of the text with elaborate inferences between the lines and beyond the text (Alptekin & Ercetin, 2011; Scales & Shen, 2004).

Table 3.3 Pearson and Johnson's Taxonomy of Reading Comprehension Questions

Level	Operations for Learning Outcomes
Textually explicit	Question and answer are cued by text language; illustrated by reading the lines
Textually implicit	Question and answer are not bound by language cue on the page; illustrated by reading between the lines
Scriptally implicit	Text question with nontextual response; illustrated by reading beyond the lines

The perspective of literal and inferential RC is similar to three levels of discourse memory (van Dijk & Kintsch, 1983)—*surface representation model* (literal RC), *propositional representation model* and *situation model* of discourse (inferential RC). *Surface representation* model refers to readers' short-lived representations and understanding of sentences or passages, which readers understand texts based on exact words and might rapidly fade out from memory. *Propositional model or situation model* refers to the psychology reality of proposition, in which readers store the meaning of sentences in mind. Sometimes making reading propositions requires readers to fill in the gap between the lines with common sense that author suppose readers would know. Namely, readers extend beyond the explicit content of texts to gain *propositional model* when they connect and make sense of chunks across the whole readings. Examples suggested by Carroll (2007) are (1) Paul walked into the room and (2) Paint was all over his shirt. With regard to inferential comprehension, it is reasonable or effortless for proficient readers to infer the possible fact that the paint might have been placed on the top of the door and fallen down while Paul was walking into the room. For literal comprehension, sentences (1) and (2) might represent two separate anecdotes. In other words, successful inferential RC or *situational model* of comprehension requires readers to connect the proposition of sentences and conjecture the missing information so as to generate a global and comprehensive understanding, or the mental representation about the reading texts.

To sum up, literal RC or *surface model* is the literal or linguistic understanding of the texts while inferential RC or *propositional/situation* model requires the readers to fill in between sentences with background knowledge and also to retain certain significant details or the meaning of presented information. Moreover, at the inferential comprehension level, readers not only maintain the proposition of information from the linguistic information of texts but also have to be aware when and how to draw inferences between the lines or across the whole passages.

Procedure

To relate participants' WMC measured with a recall-RST to their RC, 104 participants from 4 classes took the recall-RST to gain the WMC result and-completed a RC test which contained four passages with five literal and five inferential RC questions. To relate participants' WMC measured with a recognition-RST to their RC, the rest of 86 participants from 3 classes took the recognition-RST to gain the WMC result and like the recall-RST group, finished a test of RC. Both the recall-RST and the recognition-RST were displayed with a PowerPoint file on the computer monitors in front of the participants (See the clear procedure flow in fig.3.1).

The experimental procedure was undertaken around the end of the semester, and therefore some of the participants were absent for personal reasons, athletic competitions and city band practice for instance. Those absent from experiments did not show up at school till the end of the semester, which made it difficult to replenish the missing unfinished data. In the beginning, there were 112 participants in the recall-RST group and 87 in the recognition-RST. However, in the recall-RST group, 8 out of the participants could not attend the test of comprehension test. 1 of the 87 participants from the recognition-RST group missed the comprehension test.

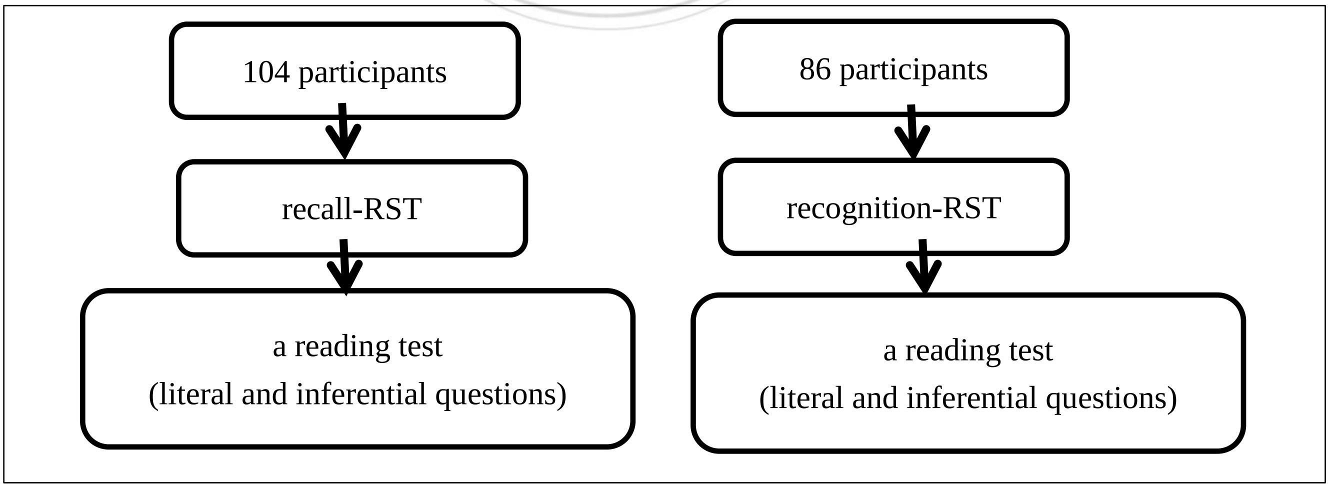

Figure 3.1 Procedure Flow Chart

Data Analysis

The purpose of this research study was to understand the relationship between WM and RC. A Pearson production correlation was applied to understand the correlation between performance of literal and inferential reading comprehension.

To answer the first research question," Is there a relationship between L2 WM recall reading span score and English comprehension accuracy in terms of L2 literal and inferential reading?," a correlation analysis was used to determine the relationship participants' recall-RST WMC and their literal and inferential RC performances. A p-value of < 0.05 was used to determine statistical significance of correlations between variables.

To answer the second research question, "Is there a relationship between L2 WMC recognition reading span score and English comprehension accuracy in terms of L2 literal and inferential reading?, "a correlation analysis was used to determine the relationship participants' recognition-RST WMC and their literal and inferential RC performances. A p-value of < 0.05 was used to determine statistical significance between variables.

The correlation coefficients, usually denoted by *r*, were used to demonstrate the strength of linear or near-linear relationship between two variables. The value of correlation falls between +1 and -1: the former indicates positive relationship, which means one variable increase along with the increase of the other; the latter indicates negative relationship, which means one variable decreases along with the increase of the other. When it comes to the significance value, p-value of < 0.05 was used to determine statistical significance. Only when the correlation coefficient reaches the level of significance would make the relationship between variables significant and meaningful in terms of statistical significance.

To answer the last research questions, "Will the influence of L2 WM on L2 RC be different if WMC is measured via these two types of RST, recall-RST and recognition-RST?" a regression analysis was applied. Regression analysis was used to evaluate the interrelationship among variables. The strength of predictive power and the relationship was demonstrated via the value of R^2 (coefficient of determination, R^2). In this study, participants' L2 literal and inferential RC performances were dependent variable, while participants' L2 recall-RST and recognition-RST WMC results measured were independent variables.

CHAPTER FOUR

RESULT

Introduction

In order to address the first and second research questions, correlation analyses were conducted to determine the relationship between WMC and participants' literal and inferential RC. A correlation analyses was used to quantify the relationship between WMC and the reading performance. The correlation coefficient represented the linear dependence between two variables and is denoted as *r* (Pearson Product Moment Correlation Coefficient). Regression analyses were presented following the correlation analyses. It was expected to demonstrate which WMC measurement methods better represented WMC and had stronger influence on RC.

Correlation Analyses of the Reading Comprehension and WMC

To address the first and second research questions, the correlation analysis was calculated. Table 4.1 showed the correlation analyses of recall-WMC and RC. Correlations of WM measured with a recall-RST and RC were 0.080 for literal, 0.144 for inferential and 0.131 for the overall RC. The significance value, p-value of < 0.05 was the criterion selected to determine statistical significance. And the significance value regarding the relationship for L2 recall-WMC was 0.422 with L2 literal comprehension, 0.144 for L2 inferential comprehension, and 0.184 for L2 comprehension as a whole. Hence, in this current study, the results did not suggest any significant correlation between recall-RST WMC and literal and inferential RC.

Table 4.1 Correlation Analyses of Recall-WMC and RC

		recall-WMC	literal	inferential	overall RC
recall-WMC	Pearson correlations	1	.080	.144	.131
	Sig. (2-tailled)		.422	.144	.184
literal	Pearson correlations	.080	1	.455**	.854**
	Sig. (2-tailled)	.422		.000	.000
inferential	Pearson correlations	.144	.455**	1	.851**
	Sig. (2-tailled)	.144	.000		.000
overall RC	Pearson correlations	.131	.854	.851**	1
	Sig. (2-tailled)	.184	.000	.000	

** Correlation is significant at the 0.01 level (2-tailled).

As for the WMC of the recognition-RST group, the correlation of WM and RC was not significant, either. The correlations were 0.168 for literal comprehension, 0.019 for inferential comprehension and 0.109 for overall RC. To reiterate, p-value of < 0.05 was to determine statistical significance. The significance value regarding the relationship for L2 recognition-WMC was 0.123 with L2 literal comprehension, 0.866 for L2 inferential comprehension, and 0.316 for L2 comprehension as a whole. Hence, in this study, the results did not suggest any significant correlation between recognition-RST WMC and RC, literal or inferential ones (Table 4.2 shows the correlation of recognition-WMC and RC).

Table 4.2 Correlation of Recognition-WMC and RC

		recognition-WMC	literal	inferential	overall RC
recognition-WMC	Pearson correlations	1	.168	.019	.109
	Sig. (2-tailled)		.123	.866	.316
literal	Pearson correlations	.168	1	.397**	.828**
	Sig. (2-tailled)	.123		.000	.000
inferential	Pearson correlations	.019	.397*	1	.844**
	Sig. (2-tailled)	.866	.000		.000
overall RC	Pearson correlations	.109	.828**	.844**	1
	Sig. (2-tailled)	.316	.000	.000	

** Correlation is significant at the 0.01 level (2-tailled).

To conclude, the Pearson correlation analysis of L2 WMC and L2 RC indicated that in this study WMC had no correlation with literal and inferential RC in this study, whether WMC was measured with a recall-RST or a recognition-RST. Statistically, correlation does not suggest causal relationship but demonstrate two variables are strongly linked—good comprehension performance come with high WMC, and vice versa. In this case, the correlation between L2 literal comprehension and L2 WMC was not significant, which is congruent with the previous literature review. However, against the previous studies, the correlation between L2 inferential comprehension and L2 WMC was not significant.

Regression Analyses of the Reading Comprehension and WMC

Table 4.3 shows the regression analysis of WMC and L2 literal RC and the analyses suggested that L2 WMC, whether WMC was measured with a recall-RST or a recognition-RST, did not account for the literal RC to a significant level (R^2=2.8%).

Table 4.3 Regression Analysis of WMC and L2 Literal RC

literal RC	model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Changes Statistics				
						R Square Change	F Change	df1	df2	Sig. F Change
recall group	1	.080[2]	.006	-.003	1.346	.006	.651	1	102	.422
recognition group	1	.168[2]	.028	.017	1.107	.028	2.433	1	84	.123

a. Predictions: (Constant), WMC

ANOVA (b)

literal RC	Model	Sum of Squares	df	Mean Square	F	Sig.
recall group	Regression	1.178	1	1.178	.651	.422[2]
	Residual	184.668	102	1.810		
	Total	185.846	103			
recognition group	Regression	2.980	1	2.980	2.433	.123[2]
	Residual	102.892	84	1.225		
	Total	105.872	85			

a. Predictions: (Constant), WMC

b. Dependent Variable: literal RC

Coefficient (a)

literal RC	Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficient Beta	t.	sig.	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
recall group	1	(Constant)	1.167	.448		3.612	.000					
		WMC	.012	.015	.080	.807	.422	.080	.080	.080	1.000	1.000
recog. group	1	(Constant)	.119	1.056		.113	.911					
		WMC	.042	.027	.168	1.506	.123	.168	.168	.168	1.000	1.000

a. Dependent Variable: literal RC

Table 4.4 demonstrated the regression analysis of WMC and L2 inferential RC. It suggested that WMC, whether WMC was measured with a recall-RST or a recognition-RST, did not account for the inferential RC to a significant level (R^2=2.1%).

Table 4.4 Regression Analysis of WMC and L2 Inferential RC

inferential RC	model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Changes Statistics				
						R Square Change	F Change	df1	df2	Sig. F Change
recall group	1	.144[2]	.021	.011	1.324	.021	2.173	1	102	.144
recognition group	1	.019[2]	.000	-.012	1.174	.000	.029	1	84	.866

a. Predictions: (Constant), WMC

ANOVA (b)

literal RC	Model	Sum of Squares	df	Mean Square	F	Sig.
recall group	Regression	3.808	1	3.808	2.173	.144[2]
	Residual	178.721	102	1.752		
	Total	182.529	103			
recognition group	Regression	.040	1	.040	.029	.866[2]
	Residual	115.693	84	1.377		
	Total	115.733	85			

a. Predictions: (Constant), WMC

b. Dependent Variable: inferential RC

Coefficient (a)

infer. RC	Model		Unstandardized Coefficients		Standardized Coefficient			Correlations			Collinearity Statistics	
			B	Std. Error	Beta	t.	sig.	Zero-order	Partial	Part	Tolerance	VIF
recall group	1	(Constant)	1.312	.440		2.980	.004					
		WMC	.021	.014	.144	1.474	.144	.144	.144	.144	1.000	1.000
recog. group	1	(Constant)	1.521	1.120		1.358	.178					
		WMC	.005	.028	.019	.170	.866	.019	.019	.019	1.000	1.000

a. Dependent Variable: inferential RC

To sum up, the table of regression analysis above suggested that L2 WMC, whether WMC was measured with a recall-RST or a recognition-RST, did not show significantly difference in accounting for the overall L2 RC (R^2=1.7%). Regression analysis is used to predict the performance of independent variables, L2 comprehension in this case, and to evaluate the interrelationship among variables. The results of regression analysis showed that the RST types of a recall-RST and a recognition-RST did not make significant difference in WMC (See the regression analysis of WMC and L2 overall RC in Table 4.5).

Table 4.5 Regression Analysis of WMC and L2 Overall RC

overall RC	model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Changes Statistics				
						R Square Change	F Change	df1	df2	Sig. F Change
recall group	1	$.131^2$	.017	.008	2.272	.017	1.786	1	102	.184
recognition group	1	$.109^2$	.012	.000	1.908	.012	1.019	1	84	.316

a. Predictions: (Constant), WMC

ANOVA (b)

overall RC	Model	Sum of Squares	df	Mean Square	F	Sig.
recall group	Regression	9.221	1	9.221	1.786	$.184^2$
	Residual	526.616	102	5.163		
	Total	535.837	103			
recognition group	Regression	3.707	1	3.707	1.019	$.316^2$
	Residual	305.688	84	3.639		
	Total	309.395	85			

c. Predictions: (Constant), WMC

d. Dependent Variable: overall RC

Coefficient (a)

overall RC	Model	Unstandardized Coefficients	Standardized Coefficient	t.	sig.	Correlations			Collinearity Statistics	
						Zero-order	Partial	Part	Tolerance	VIF

			B	Std. Error	Beta							
recall group	1	(Constant)	2.929	.756		3.875	.000					
		WMC	.033	.025	.131	1.336	.184	.131	.131	.131	1.000	1.000
recog. group	1	(Constant)	1.640	1.820		.901	.370					
		WMC	.047	.046	.109	1.009	.316	.109	.109	.109	1.000	1.000

a. Dependent Variable: overall RC

Collectively, in this study under two types of L2 RST, L2 WMC demonstrated no relationship with literal, inferential and also overall RC. Also L2 recall-RST and L2 recognition-RST did not correlate L2 WMC to RC to a significant level.

CHAPTER FIVE

DISCUSSION

This chapter was divided into three main sections, each of which presented the discussions relating to each research question.

In the discussion that follows, each of the three research questions was examined and discussed in further details. Also, the consistence and inconsistency of results in this study with previous studies were illustrated as well. Possible explanations and discussion for the results of this study was presented and developed based on review of relevant literature. The major findings, limitation and pedagogical implications of the present study's findings for future research and practice were included in the last chapter.

The Influence of WM on Literal Comprehension

One of the goals of the current study was to understand whether L2 WM is significantly correlated to L2 literal RC. The first hypothesis predicted no significant correlation between L2 WM and L2 literal RC. This hypothesis was supported in this study.

Previous studies indicate that constructs of L2 literal comprehension and L2 WMC are different, which leads to the weak correlation between literal RC and WMC (Altepkin & Ercetin, 2010; Miyake & Friedman, 1998). First of all, when making literal RC, L2 readers tend to focus on decoding the factual and surface information of the reading texts. On the contrary, the function of WM is to offer adequate cognitive mental space for individuals to complete demanding cognitive tasks. Literal comprehension can be regarded as readers' first step when they become engaged in the linguistic messages, and perhaps they would make further relevant propositions from sentences in close proximity so as to formulate a coherent minimally semantic structure (King, 2007). According to Altepkin and Ercetin (2001), L2 readers are prone to generating text-based RC. Therefore, their comprehension is mostly devoted to understanding explicit textual information, instead of implicit or hidden messages behind the linguistic clues. L2 literal RC is built by automatically recognizing information stated literally from texts and less demanding than making inferential RC. WM works as mental space that can temporarily store and process immediate information, which goes beyond the factual and surface understanding of texts. The construct of literal RC partially corresponds to the information-decoding part of WM. Therefore the discrepancy between WM and literal RC weakens the correlation between WM and literal RC. Therefore L2 literal RC has no significant correlation with WM.

Secondly, Daneman and Hannon (2007) indicated that WMC contributed little to the performance of RC in adults when the variable of higher-level processes, such as inferential reading, was excluded from the participants' overall RC. Namely, WMC accounts for little variation in literal RC because WMC is more related to highly demanding cognitive tasks rather than surface understanding as literal RC. Literature shows that L2 readers with higher WMC can make better reading inference and that WMC has minor influence on literal RC (Chiappe, Hasher & Siegel, 2000). According to Daneman and Hannon (2007), WMC contributes less to RC performance when inferential RC or higher-level process is taken out from comprehension as a whole. In other words, WMC has little relationship with lower-level word process or literal RC. Furthermore, as Miyake and Friedman (1998) indicated, L2 WMC can be regarded as a great determinant for making syntactic RC. As Miyake and Friedman (1998) observed, L2 WMC plays an important role when readers perform complicated and challenging tasks, such as syntactic RC or comprehension behind the sentences. In other words, L2 WMC would demonstrate its influence on L2 comprehension when the cognitive tasks are challenging to the mind and cause cognitive demands on L2 WMC.

When it comes to WMC and the degree of challenge readers have while reading, studies indicate that high-/low- level WMC differ in terms of degrees of cognitive load (Dennis & Barnes, 2001; Sweller, 1994). Higher WM enables readers to comprehend automatically fluently, forming meaningful conceptualization of immediate messages in order to prevent them from overloading the working memory space with overwhelming information. Higher WMC eventually benefits readers in terms of inferential reading. In other words, higher WM readers are able to fluently comprehend the linguistic clues in the reading, and better at manipulating the current information. They could connect the texts at hand to his or her own long-term memory and background knowledge more smoothly and automatically than those with lower-level WMC.

In addition, high-WMC readers have better function of *inhibition* and also better control of their attention, which enables them to be better at focusing on the current tasks under the manipulation of *central executive* (Baddeley, 2012). *Inhibition* is the capability of suppressing irrelevant information while attending to the current task with clear goals. Such features are quite similar to the *cocktail party effect*, which refers to an ability to ignore the irrelevant stimuli and effectively direct one's own attention to necessary information regarding the goal of tasks at hand (Engle et al., 1999).

For L2 readers with lower level of WMC, it is difficult to retrieve information from the LTM rapidly with less automaticity and to temporarily store the current information from the reading. The reason is that L2 readers with lower level of WMC tend to maintain irrelevant information and thus consume their mental space with high percentages of information loss. It leads to less contribution to forming and manipulating information in the WM. Therefore, lower-WMC L2 readers might fail to surpass high-WMC readers in terms of inferential RC.

To conclude, in this study, WMC measured with a recall and a recognition reading tasks failed to demonstrate significant correlation with literal RC, which was consistent with the previous studies (Altepkin & Ercetin, 2010; Chiappe, Hasher & Siegel, 2000; Miyake & Friedman, 1998). The result confirms the generally accepted view in the literature that L2 WM has no relationship with L2 literal comprehension.

The Influence of L2 WMC on L2 Inferential Comprehension

The result of the current study did not detect any evidence for any significant correlation between L2 inferential RC and L2 WMC, whether L2 WMC was measured with a L2 recall-RST or with a L2 recognition-RST. Neither did the study done by Chun and Payne (2004). Considering the numerous studies supporting the positive influence of WMC on inferential RC (Altepkin & Ercetin, 2001; Anderson et al., 1996; Baddeley, 2012; Conway & Engle, 1994; Daneman & Hannon, 2007), the result of the present study should be considered tentative and the power of generalization should be taken with restrictions. However, the following discussion provides possible reasons based on theoretical opinions about WM and RC for the discrepancy from previous studies.

Previous studies have reported that higher-WMC L2 readers are able to make better reading inference than those with lower-WMC L2 readers (Alptekin & Ercetin, 2009, 2011; Anderson et al., 1996; Baddeley, 2012; Chiappe, Hasher & Siegel, 2000; Conway & Engle, 1994; Pulido, 2009). Inferential comprehension refers to a deeper understanding of the content of the text in comparison with literal comprehension. Higher WMC enables readers to efficiently delegate information through *central executive* or to attentively focus on immediate tasks. Furthermore, readers with high WMC have better *inhibition* and can deal with tasks with concentration under the manipulation of *central executive* (Baddeley, 2012).

Also, with higher WMC, readers' cognitive space for processing and storing new and old information would be adequate to fluently deal with demanding tasks, such as making reading inferences. Particularly, Koda (2005) indicated that the processing of L2 WMC demonstrates similar characteristics when individuals undertake high-order cognition tasks, which makes L2 WM highly correlated to L2 inferential RC in numerous of previous studies (Dennis & Barnes, 2001).

Nevertheless, according to Daneman and Carpenter, all individuals with high WMC or low WMC, might have the same or similar capacity of WM. In other words, WMC is not a stable or fixed trait for individuals, like gender or nationality, and WMC might change along with time, place or under other situations. Those who make correct reading inferences efficiently in one reading text demonstrate high WMC. But they might encounter reading difficulty and demonstrate lower WMC in another reading text. This happens from time to time when skilled readers are forced to read texts the content or the topic of which are unfamiliar to his or her background knowledge or irrelevant to his or her interest, their eye movement deteriorates. They might have poor or shallow comprehension about the very text (Stanovich, 1986). Shallow comprehension means that skilled readers' WMC space is overly consumed and occupied with literal information, and therefore weakens and deteriorates the WMC of skilled readers. Genres, domain knowledge, readers' mental and physical situation or other factors would account for the change of WMC for one individual. To be specific, Daneman and Carpenter (1980) argued that individuals possess similar WMC and the significant difference in comprehension mainly results from reading skills, not from the capacity of WM. Those with good reading skills consume less WMC and they have more cognitive space to process information than readers with inferior reading skills. Therefore, those with better reading skills have much more cognitive space and high capacity of WM. That is, how higher WMC is related to better both literal and inferential RC. From this perspective, having good reading skill is an essential variable when it comes to the relationship between WM and RC.

Like Daneman and Carpenter, Ericsson and Kintsch (1995) suggest that readers' WMC changes along with immediate reading tasks. The changes of individuals' WMC result from their background knowledge about the texts at hand (Kintsch & Ericsson, 1995). Kintsch (1995) suggests that individuals' WMC might be expanded or consumed based on how much background knowledge readers have about the immediate reading tasks. WM, a rather limited cognitive space, in other words, would be expanded with resources from LTM and there would be enough cognitive space for immediate cognitive tasks. L2 readers are likely to encounter reduced working memory spans when involved in L2 input, and this phenomenon of reduced WM results from the lack of adequate LTM contributions to L2 WMC (Brown & Hulme, 1992).Thus, long term WM could be defined “as the part of the LTM that can be accessed rapidly and reliably by means of retrieval cues in WM” (Ericsson & Kintsch, 1995).

From this perspective, the predictive power of WMC on cognitive tasks depends on at least two factors: one is the short-term working interface of storing and processing information and the other is the resources from individuals’ background knowledge of LTM. While WM stores and processes incoming information through sensory stimuli, from reading texts for one thing, it mediates among perception, LTM and actions. And resources from LTM has great influence on how well the immediate information is processed (Baddeley, 2012). In other words, WM varies with individuals’ background knowledge about texts and also with the difficulty level they encounter in every different text. Readers’ resources in LTM-working memory reduce the consumption of readers’ WMC and more cognitive space is saved to deal with information. Therefore, readers’ background knowledge and reading skills are strong factors when it comes to the influence of WM on RC. Also according to Hannon (2012), L2 WMC sometimes has indirect influence on L2 inferential comprehension. L2 WMC serves as an efficient workspace for readers to combine and formulate comprehensive understanding toward the reading texts; however, lack of other important resources, such as background knowledge or trained reading speed, would severely deteriorate the comprehension performance, especially when individuals deal with demanding comprehension tasks.

Another possible explanation for the inconsistent finding regarding L2 WMC and L2 inferential RC might result from the difference between the characteristics of L1 and L2 readers. Alptekin (2004) suggests that L2 readers tend to perform similarly like insufficient L1 readers for L2 readers usually build up their comprehension literally. That is, it is not the first instinct or habit for L2 readers to infer beyond the linguistic information during the reading process. It takes guided attention or trainings of reading strategies to assist L2 readers to make correct reading inference. In this study, as the descriptive analysis showed, the participants found the reading texts difficult to understand literally, which made it even harder to make correct reading inferences beyond the texts. It could be imagined that in this study readers only stored linguistic information, leaving short of deeper understanding. Therefore, the participants' L2 inferential comprehension performances were similar to their L2 literal comprehension performance. L2 readers tend to have "shallow textual representation" of the reading, and therefore they tend to make false reading inferences (Alptekin & Ercetin, 2011, p.237). When it comes to L2 literal comprehension, L2 WMC has no significant influence on L2 literal comprehension (Altepkin & Ercetin, 2010; Miyake & Friedman, 1998). In other words, the results of L2 inferential comprehension could not fully represent the participants' ability to generate correct inferential comprehension. The result might have shown a strong correlation between L2 WMC and L2 inferential RC if the participants had less reading difficulty. This flaw of research design, such as reading difficulty of the given RC test, was elaborated in the limitation section of the next chapter. Relevant factors resulting from the research design for the result about L2 WMC and L2 inferential RC in this study was further included in the following.

RST Types and WMC

Finally, the result showed that the recall-WMC and recognition-WMC had no relationship with RC. It was assumed that L2 recall-WMC had a stronger relationship with L2 inferential comprehension than L2 recognition-WMC does. First, literature shows that L2 WMC is more related to L2 inferential comprehension (Alptekin & Ercetin, 2011;

Kane et al., 2001; Nassaji, 2002; Unsworth & Engle, 2007). Secondly, recall-RSTs are better to evaluate and represent L2 WMC than recognition-RSTs do (Unsworth & Engle, 2007). Therefore, it was hypothesized that L2 WMC has positive correlation with L2 inferential RC when WM is measured with a L2 recall-RST, rather than with a L2 recognition-RST.

With regard to constructs behind these two RSTs, first of all, recall-RST requires participants to do dual-task simultaneously—judging the grammaticality of presented sentences and memorization of ending words. In this case, participants do what they do to process and store information in WMC—to store and process information at the same time. On the contrary, when taking the other kind of WMC RST, the recognition-RST, participants judge sentence grammaticality while reading sentences and recognize ending words from a list of provided words. To complete a recognition-RST, participants, recognizing ending words instead of memorizing and spelling them, simply store the immediate information without the process function in recall-RST tasks. Making reading inferences and completing the recall-RST both require participants to do the similar cognitive tasks—to temporarily store information and process, linking new information to knowledge withdrawn from LTM. Hence, some researchers have considered the influence of WM on RC is strong when WMC is measured with a recall-RST (Altepkin & Ercetin, 2009; Unsworth & Engle, 2007).

Apart from the original hypotheses and expectations, the regression analysis of the current study showed that L2 WMC, measured with a recall-RST or with a recognition-RST, did not show significant power on predicting the performance of overall L2 RC (R^2=1.7%). Although the results of regression analysis showed higher accountability of L2 recall-WMC than that of L2 recognition-WMC, the accountability power was still not statistically significant.

Previous studies concerned with RST types and the influence of WMC have different opinions.

First, WMC measured with both a recall-RST and a recognition-RST demanded similar cognitive loads on participants. Due to the lack of a significant correlation between WMC and RC in this study, both recall-WMC and recognition-WMC were not significantly correlated to RC. According to Turner and Engle (1989), RST of all kinds could tap the same variation in reading comprehension regardless of WMC tools (a recall-RST and a recognition-RST). The results showed that the WMC of these participants in this study did not have strong correlations either with their literal or inferential RC. If both the recall-RST and recognition-RST could tap the same variation in RC when WMC was not highly related to RC, it was reasonable that the recall-WMC and recognition-WMC had no relationship with RC.

However, some researchers with different opinions from Turner and Engle suggest that different constructs are assessed in different RSTs (Alptekin & Ercetin, 2009; Unsworth & Engle, 2007). The recognition-RST measures the participants' abilities to recognize the ending words from the provided options or "externally presented retrieval cues" (Unsworth & Engle, 2007, p.112). The recognition of externally presented cues might only activate short-term memory.

To complete a recall-RST, participants recall the stored item, the ending words, from their internally generated cues. It requires the long-term memory of participants to memorize or link all the ending words. Though differences exist in terms of cognition demands in both RSTs, others still think both a recall-RST and a recognition-RST require knowledge from LTM (Alptekin & Ercetin, 2009). It seems that recognizing ending words from the provided list does not activate LTM knowledge. But it would be difficult and impossible for the participants to temporarily keep the ending words in mind for the later test of word recognition without knowing the words in the first place. Thus, the operation of both a recall-RST and a recognition-RST consumes and requires LTM knowledge to certain extent. One of the research questions was concerned with whether or not these two RSTs demonstrate difference in assessing the influence of WM on RC. Judging from the result, still more studies are needed in order to understand the distinction between these two RSTs or among other RSTs.

Even though it was uncertain whether different RSTs assess different or the same cognitive variation in terms of WMC operation, the non-significant correlation might not result from this uncertainty. While participants were taking the RST, they stored and processed information under clear guidance and fixed time periods. Their attention was focused on comprehending the sentences presented at presence while they judged the grammaticality and memorized the ending words at the same time. To complete the RST, participants had a simple mission and a clear goal. To complete the recall-RST and the recognition-RST, special reading skills or background knowledge about the sentences were not needed in order to fully comprehend the sentences since the 42 sentences were all simple narrative sentences. RSTs are designed to examine participants' abilities to comprehend texts and process information, not to measure their size or scope of memory (Baddeley, 2002). To complete the later test of RC, they deduced or inferred explicit and implicit information. Their RC performance involved not only their WM ability to store and process information but also their reading skills and background knowledge. When participants took the RC test and tried to comprehend the given text, they acted independently without clear guidance to seek out the mission goals and to control their attention. WM, as suggested to have great influence on RC, supports readers in processing and storing information. But more variables are essential for making correct and deeper understanding about texts beside the variable of WM.

As researchers point out, reading skills and background knowledge are also important for readers to glean scattered information across the texts and to form a solid comprehension (Daneman & Carpenter, 1980; Kintsch, 1995). Previous studies about

WM and RC take a simple research procedure of WMC RST and the test of RC; other relevant factors about RC are often not included into consideration, such as participants' background knowledge, reading skills or attention. Based on the result of this study and the discussion here, it requires more than one single factor (WM in this study) regarding the power of WM on RC. Other relevant factors should be taken into research design for future studies.

CHAPTER SIX

CONCLUSION

Summary of the Study

This study tried to duplicate the influence of WM on L2 RC, especially the literal and inferential RC.

Besides, since the difference of WM measurements (RSTs) has often been neglected in studies, it was one of the interests to testify whether the influence of WM would vary mainly when WMC is measured with a recall-RST and a recognition-RST. The result of the current study indicated that L2 WMC of the participants in the current study did not have significant correlations with their literal and inferential RC. The final results regarding two types of RSTs showed that the influence of WM on RC did not vary to a significant level. Thus, the findings of the study could be interpreted with the caveat that the efficiency or performance of one's cognitive tasks depends not only on WMC but also other relevant factors, such as reading skills, background knowledge and readers' devotion to reading. The positive influence of WM is prone to deterioration and it was not easy to relate WM to RC. The lack of stability of WMC suggests that one person's WMC might change from task to task. The lack of stability in individuals' WM might also happen in the case of taking RST and a RC test; one could have high WMC when taking a RST but demonstrate lower WM when taking a RC test. Their poor reading skills and inadequate background knowledge consume his or her WM. It remains uncertain whether recall-RSTs could better assess WM than recognition since there are two sides of theoretical discussion as mentioned above.

In sum, L2 WMC is not correlated to L2 literal RC based on the results of this study and other previous research (Altepkin & Ercetin, 2010; Chiappe, Hasher & Siegel, 2000; Daneman & Hannon, 2007). In other words, the function of WMC works as a highly-efficient system of information manipulation. Thus it has little influence on automatic recognition of information without the need to further syntheses or inference, such as L2 literal RC.

When it comes to the robust correlation between WMC and inferential RC, it is difficult to testify with simple one-time research design in the current study—a WMC RST and a test of students' comprehension performance (Altepkin & Ercetin, 2010; Anderson et al., 1996; Baddeley, 2012; Conway & Engle, 1994; Daneman W. & Hannon, 2007). First of all, individuals' WMCs change. WM is not a stable strait or characteristic for an individual reader. Some readers might demonstrate high WMC in one task but lower WMC in another task. Their reading skills, background knowledge or attention carry severe influence on the influence of WMC on L2 inferential RC. Seemingly, WMC is unfortunately limited in certain ways regarding the power of WMC on learning or cognitive activities (Gathercole & Alloway, 2007). Distractions or overload of information that happen during the process of undertaking cognitive tasks would definitely weaken the influence of WMC on individual's learning performance, like RC (Blalock & McCabe, 2011; Conway, el at., 2007; Just & Carpenter, 1992; Kane et al., 2001). The influence of WMC on cognitive tasks would deteriorate when individuals are faced with far too demanding tasks. Too demanding or difficult tasks would reduce the mental space of WMC, even for readers with high WMC. In this case less cognitive space is left for high-level cognitive tasks.

Secondly, other relevant factors are participants' background knowledge and reading skills as mentioned in the previous discussion section (Daneman & Carpenter, 1980; Ericsson & Kintsch, 1995). Those relevant factors, if not controlled, might interfere with the duplication of WM being predictive of RC. How the previous studies successfully correlate WM to RC without controlling more variables is unknown and intriguing to find out. However the correlation between WM and RC was difficult to be confirmed in a simple one-time procedure like the research design of this study. More thorough research design in future studies is needed to testify the predictive power of WMC on L2 inferential RC. Other variables, such as background knowledge and reading skills, can be included as independent variables.

When I first worked on the literature and research design of this study, I reviewed lots of studies supporting the predictive power of WM on RC. I therefore had come to a misunderstanding that those who performed well in RST, or readers with higher-WMC, would always end up with better comprehension about any text. In the data analysis phase of this study, I felt frustrated and devastated to find out the statistics did not show any significant correlation between WMC and RC. Going through lots of literature reading and struggling with myself, I suddenly realized that WMC changes to be higher or lower under certain circumstances or under different reading tasks (Daneman & Carpenter, 1980; Ericsson & Kintsch, 1995). Those who have ever gained higher scores in RST might demonstrate malfunction of their high WMC. As mentioned above, WMC is not a stable trait for individuals, like gender or nationality, and WMC might change over time, place or under other situations. A reader could demonstrate high WMC in one text but lower WMC in another. Reading skills and resources form background knowledge would account for the changes of WMC in the very reading text and also for the performance of RC. Many researchers agree that WMC plays an essential role in inferential RC, but as previous discussion suggests a person's WMC changes with immediate texts (Daneman & Carpenter, 1980; Ericsson & Kintsch, 1995). In previous studies that support the influence of WM on RC, participants take a RST and a test of RC. Chances are the condition of one's WMC when they take RST is not the same as in comparison with his or hers WMC on another later test of RC. To rule out the possibility whether WM might vary from task to task, future studies could try to gain the WM and RC performance in on task, rather than comparing the WMC in one task (a RST) and their performance in another task (a RC test) . On the other hand, doubts are how the previous studies could successfully relate the WMC results from RST to participants' RC performance. My reasonable speculation is the stable reading ability and reading condition, whether participants' attention or their background knowledge, are quite the same in both RST and the follow-up RC test.

In sum, WM can positively influence the outcome of demanding cognitive activities in that it is responsible for information manipulation which requires skilled operation to integrate new and old knowledge under attentive situation. Scholars suggest relevant factors that would deteriorate the influence of L2 WMC on L2 inferential comprehension, like readers' background knowledge, attention control and inhibition of irrelevant information, participants' attitude and motivation toward the experiments (Brown & Hulme, 1992; Chun & Payne, 2004; Daneman & Carpenter, 1980; Ericsson & Kintsch, 1995; Hannon, 2012). L2 WMC is seen as a mechanism that efficiently manipulates incoming information and forms a comprehensive understanding with new and old knowledge. Relevant factors to WMC, factors mentioned above and others related to readers' mindset in dealing with demanding reading tasks, should be controlled in research design in order to testify the relationship between L2 WMC and L2 inferential RC.

Limitation

The result of the present study should be considered tentative and the power of generalization should be taken with restrictions. Several relevant factors restricting the result of this study were elaborated as follows.

The first limitation is the sample size.

The investigator included these 190 students without similar language proficiency in the current study. There were some obstacles for the feasibility of the study. First of all, under the restriction of course schedules at school, it was unlikely to withdraw students of the same language proficiency from my school and to stop them from attending their scheduled classes. In order to include as many participants as possible in the research, I asked many classes for permission to participate the study and only the teachers of these 7 classes agreed to spare some periods for conducting this experiment in class. Secondly, the number of students passing the GEPT elementary level in the researcher's school was around 30. If I only had included 30 participants in the study, the number of participants would have been too few and would have sabotaged the analytic generalization. Furthermore these qualified students were in different classes and grades. Averagely one class had two to four students who had passed the GEPT elementary level. Thus, I had to forgo the idea of including participants above certain English proficiency but to adopt a convenient sample of six classes instead. These students with varying language proficiency and different reading skills formed a heterogeneous group. The number of 190 students from the 7 classes was appropriate for analytic generalization.

Sample size is crucial when it comes to the influence of WM on RC. Although WM is related to L2 language comprehension and use, studies regarding the magnitude and effect of WM have somehow been inconsistent among studies. Some suggest the inconsistency might result from variation of population effect size (e.g., measurement errors or sampling error); some suggest the possible reason is the systematic difference regarding WM theoretical framework. A similar study result of non-significant correlation between WMC and inferential RC was found in the study of Chun (2000). According to Chun (2000), the result suggested that the individual difference among readers, such as readers' L2 WMC in this study, does not or might not affect RC performance. Chun (2000) suggests, small sample sizes of participants, participants' attention to tasks, and the authentic nature of research-conducting situation might lead to masked research results—no significant correlation between L2 WMC and L2 inferential comprehension.

In Chun's study, participants were allowed to have access to annotation resources about the research reading texts if necessary when completing comprehending tests with a multimedia access in that study. When discussing the implication behind the research result, Chun recalled that some participants only completed parts of the research procedure. Few of the participants in that study did not "take the test very seriously" as observed by administration instructors (Chun, 2000, p.498). In that study, Chun indicated that factors like sizes of samples and participants' attitude tremendously deteriorated the relationship of L2 WMC and L2 inferential comprehension.

The second limitation is the participants' awareness of the importance of the studies.

When it comes to participants themselves, one of the crucial experimental factors indicated by Chun in her study, the current research was conducted at the end of the semester, right after the final examination and before the winter vacation. Just finishing the final exam, most participants lacked intrinsic motivation toward taking the reading comprehension test—it was not a high-stake examination and no immediate reward was provided. During the process, some of the participants gave up trying to understand the reading texts and claimed it was too difficult for them to read. Specifically, about 1/6 participants scribbled down their answers without prudent reading and thinking while other peer struggled to finish the test at the first 20 minutes of the procedure. Furthermore, for those who were willing to try overcoming this reading test might not use proper reading strategies. Many of the participants were found to be stuck at one reading for quite a while. To be specific, the testing period lasted for 45 minutes but many participants spent almost 20 to 30 minutes on the first text leaving inadequate time for other 3 texts. All these variables and individual difference greatly masked and compromised the research result to a certain extent and led to the inconsistent result that L2 WMC failed to reveal significant correlation with L2 inferential RC.

In Chun's study, she included 19 undergraduate L1 students enrolled in one of the university in the West Coast of the US. Since Chun intended to investigate four variables besides WMC and RC, participants in his study were allowed to consult Internet resources in case of having difficulty understanding the readings. According to Chun (2004), the non-correlation between WMC and RC might result from the not-regulated reading time and participants' ignorant attitude toward research tasks. As Chun (2004) noted, "a larger sample with more complete language data on the language performance measures would generate a different set of results" (p.497). In other words, as Chun indicated, the failure of demonstrating participants' language competence and engaging participants in completing research tasks could deteriorate the relationship between WMC and reading comprehension. Likewise, Jeon and Yamashita (2014) pointed out that most studies on L2 WMC and L2 reading comprehension included low or not enough numbers of effect sizes, which means that accumulated evidence gleaned from researches is insufficient to generate trustworthy implication regarding L2 WMC and L2 reading comprehension. Hence, the sample size and the participants' attitude are two significant factors in influencing the research result.

Table 6.1 Descriptive Analysis on Reading Span Task (RST) of the 190 Participants

		number	minimum	maximum	mean	SD
recall-RST group	WMC	112	0.20	12.00	8.3168	2.54938
	literal RC	104	0	5	1.96	1.343
	inferential RC	104	0	5	1.93	1.331
	overall RC	104	0	5	3.89	
recognition-RST group	WMC	87	3.45	12.00	11.1768	1.39676
	literal reading	86	0	5	1.76	1.116
	inferential RC	86	0	5	1.71	1.167
	overall RC	86	0	5	3.47	

To reiterate, participants' attention and text difficulty of the provided reading comprehension in studies are important factors regarding the power of implication behind the research result. In terms of the participants' overall RC including literal and inferential RC, the mean scores of RC were 3.89 for the recall group and 3.47 for the recognition group (Table 6.1 shows the descriptive analysis of participants' WMC and RC performances). In terms of performances of literal RC, the mean scores of RC were 1.96 for the recall group and 1.76 for the recognition group. In terms of performances of inferential RC, the mean scores of RC were 1.93 for the recall group and 1.71 for the recognition group. Besides, the SD (standard deviation) for the recall groups was 1.343 for their literal RC and 1.331 for their literal RC. The SD for the recognition group was 1.116 for their literal RC and 1.167 for their literal RC. This small gap among these SD implied that the RC performances of all participants in both the recall-RST and the recognition-RST groups were quite close to each other. Standard deviation is used to demonstrate the situation in which data points are spread out in the area of statistic values. Considering the total score of the experiment reading test being 10 points, the SD values (1.343, 1.331, 1.116 and 1.167) indicated that the discrete degree of RC among participants was low. Besides the density of the cross-participants RC performances, the general RC performance of all participants seemed to be low and not high. As for other descriptive analyses, the maximum scores of RC were 10 for the recall group and 9 for the recognition group; the mean scores of RC were 3.89 for the recall group and 3.47 for the recognition group. To sum up, the descriptive statistic of mean scores and SD indicated that this reading test was difficult and challenging for most participants regarding the poor RC performance indicated by the mean scores and SDs mentioned above.

Likewise, several researchers emphasize that individual differences in WMC are less contributable to real storage of information but more to one's ability to control attention in dealing with cognitive tasks (Engle, 2002; Engle & Kane, 2004). According to Engle and Kane, readers with high WMC have better attentive control to process new and old information when dealing with cognitive task demands. Literature suggests that the interaction or interplay of storage and process within WMC would be mediated by participants' selective attention—the function of inhibition or oppressing the minor information (Engle et al., 1999; Conway, 1998). In other words, participants' control of their attention to relevant information regarding the immediate tasks at hand is essential in terms of generating a successful comprehension and performance. Thus, participants' attention control is highly related to central executive component inside WMC and greatly accounts for the situation how individuals deal with cognitive tasks, such as RST and RC tests. Readers' attention is emphasized when it comes to WM and cognitive tasks. The information stored in the slave systems of WM would last and maintain in readers' mind in an active form for a short period of time, "unless constantly rehearsed" or delegated in task performance under the control of *central executive* (Jerman, Reynolds & Swanson, 2012, p.144). Successful cognitive actions require temporary storage and manipulation of current information along with relevant resources from LTM background knowledge. The insufficient level of attention deteriorated the influence of L2 WMC on L2 inferential comprehension performance.

Specifically, according to Engle and Kane (Engle, 2002; Engle & Kane, 2004), tasks to which participants hold full attention, such as RC, would fully reveal or demonstrate the predictive power of WMC, either in the case of L1 and L2. Conversely, WMC would be revealed to be unrelated to tasks in which participants simply complete with automatic processes instead of fully activating their mind power to infer further comprehension. When it comes to automatic process for comprehension, one example is literal RC. Literal reading comprehension requires readers simply to choose the words they recognize from the text. In doing so, some fail to connect the proposition from sentences into a coherent meaningful representation which might not be stated explicitly from the print text. Most important of all, it is the participants' abilities that could wield the influence of central executive to manipulate the task-relevant information so as to accomplish complex cognitive tasks.

The third limitation is the study design of reading skills and background knowledge.

First of all, the reading texts were adopted from the standardized exam of CAP (Comprehensive Assessment Program of Junior High School Students) and were found to be too difficult in comprehending for most of the participants in this study. The mean scores of overall RC performance were 3.89 for the recall WMC group (N=104) and 3.47 for the recognition WMC group (N=86) while the total reading score was 10. When it comes to L2 inferential RC, the mean scores were1.93 for the recall WMC group and 1.71 for the recognition WMC group under the premise of total inferential RC score (=5) . In order to ensure the reliability and validity of reading texts, the texts of reading were adopted from the English standardized test of CAP (Comprehensive Assessment Program for Junior High School Students) in 2014. Four reading passages with 5 literal and 5 inferential RC questions were included. According to an official report regarding the item difficulty of English test from CAP (2014), this newly-reformed reading exam requires test-takers not only to understand reading literally but also to go beyond the text and form coherent comprehension within the context. In this study, the participants ranged from 8th to 9th graders and did not complete the whole three-year English course in junior high school. In order to alleviate possible reading difficulty or problem from unknown English vocabulary, necessary Chinese counterparts for some English vocabulary, which had not included in their textbooks, were provided in the tests. The difficulty understanding the texts greatly overloaded the participants, which resulted in little space to process and synthesize information (Conway, el at., 2007; Just & Carpenter, 1992).The information overload on readers led to the same result of no significant correlation. According to the WM capacity theory, comprehension performance "declines with an intrinsic memory load or an extrinsic one"(Just & Carpenter, 1992 , p.135). Possible intrinsic memory load requires readers to retain information across successive sentences of a text. In terms of the inferential RC performance in the present study, comprehension difficulty and unfamiliarity about genres and comprehension strategies overloaded participants' WMC. Studies in second language (L2) reading have suggested that L2 learners are able to gain extra additional information about the language or the text when the information is well decoded (Pulido, 2003; Rott, 1999). Namely readers better comprehend a text when he or she has certain knowledge about the text structure or the text content. Because the reading process for L2 readers is dynamic which involves a number of factors, relevant variables, such as readers' background knowledge, aptitude and memory constraints interact with text variables (e.g., text structure, length, syntactic and lexical complicity).

Also, as the WM capacity theory suggests, in the case of information overload on readers, less WMC space will be left for participants to integrate the incoming information. In the long run, readers would find it difficult to control their attention to be able to integrate the segments from the texts into a comprehensive mental representation, letting alone generating deeper inferential comprehension beyond the print (Engle, 2002; Engle & Kane, 2004). Same emphasis of attention control appears in studies which indicate that three factors would diminish the predictive power and construct validity of WMC—tasks completed with automaticity, less attention to tasks or information overload (Kane et al., 2001; Blalock & McCabe, 2011). As mentioned above, when more than one tasks or cognitive activities are required to be processed, the resources or space would be compromised under the competition among the needs to deal with tasks at hand. Eventually, it increases the burden on *central executive* and slows down the efficiency to complete the immediate task. Due to this, it makes WMC related to cognitive tasks and the efficiency of accomplishing them. Again, participants' attention and the information load for readers are essential for task performance.

Last but not least, the participants were still in the early stage of learning English as a second language and more cautions should be taken regarding the validity of RC tests. Ericsson and Kintsch (1995) note that the capacity of one's WM could be expanded with resources from LTM (long-term memory) knowledge. Similarly, Brown and Hulme (1992) hold the view that L2 reading performance of ELLs tends to be lower than their L1 performance due to inadequate LTM knowledge contributing to WMC. The *inhibition* in WM of L2 readers does not function better than those with higher-WMC and hence does not prevent information from overloading WMC of lower-WMC L2 readers. In the long run, L2 readers with low-WM capacity tended to focus on textual clues and failed to conduct higher-level conceptual process of reading. Consequently little cognitive space of information contribution from LTM to WM was left and also little space was left for WM to do higher-level cognitive tasks (Alptekin & Ercetin, 2009; Pulido, 2009).

In other words, L2 readers with low-WM capacity might not encounter difficulty comprehending literal messages, but they might not be able to infer and integrate the textual and prior knowledge fluently. This overemphasis on reading literally for some L2 readers would lead to their false inferential RC, which implies that poor comprehension might not always result from incompetent language proficiency but some might result from WM limitation (Pickering, 2006). This would be consistent with the automaticity theory: "slower word process consumes too many working memory resources" and readers then fail to perform smoothly in high-level cognitive tasks (Hannon, 2012, p.147; LaBerge & Samuels, 1974). Thus, readers' attention is important when it comes to WM and demanding cognitive tasks in which the information manipulation is controlled by *central executive* inside WM.

According to Kintsch et al., (1999), the more complex a task is, the more it needs the contribution from LTM background knowledge contributing to the comprehension-forming process in WM. For instance, the completion of high-level cognitive tasks, such as inferential RC, depends on adequate resources of LTM-based knowledge supporting the function of WM (Calvo, 2001). When readers lack sufficient knowledge about texts, they tend to excessively focus on surface or proposition-level information occupies much cognitive space, leaving less for allocation of LTM knowledge. Allocation of background knowledge is essential for generating meaningful and coherent inferential RC (Pulido, 2009). Judging from the result of this study, future studies could be focused on finding out the threshold of RC difficulty in studies about WMC and RC in order to efficiently testify the influence of WMC on RC.

Readers with high L2 WM are more capable of controlling attention to task-relevant information and of linking old and new information into a new coherent representation (Baddeley 2002). Hence, L2 WM serves as a readers' advantage in the face of difficult cognitive tasks. However, readers with insufficient background knowledge, regarding the language or the characters of the texts, or with wandering attention, might not be able to generate a correct and coherent comprehension, surface or deep, even with high L2 WMC. Taken together, the result of this study provided new insights into the necessity of reading instruction from multiple approaches—background knowledge, ability to control and focus in the face of immediate cognitive tasks.

This study was aimed at replicating the influence of WMC on RC when English is learned as a foreign language. According to research, FL readers tend to focus on surface comprehension. Reading can be difficult and complex even in one's native language, and the degree of difficulty and complication is much greater in FL (foreign language) (Harrington & Sawyer, 1992; Horwitz, Horwitz, & Cope, 1986; Miyake & Sawyer, 1992). FL readers mainly rely on their knowledge of L2-specific knowledge, grammar and vocabulary for instance, at early stage of learning L2 (Hdstijn & Bossers, 1992). Therefore, it is highly likely that L2 readers at the early stage of L2 learning have difficulty making pragmatic inferences (Chun, 2004). According to McVay and Kane

(2012), incompetence L2 readers, or novice readers, are inclined to read literally and have shallow or wrong inferential reading comprehension. In other words, WM operation in the case of L2 readings is influenced by “cognitive deficit”, which refers to the processing limitation of L2WM in L2 RC (Alptekin & Ercetin, 2011, p.236). Due to this characteristic of cognitive deficit for L2 readers, according to Lee (1986), the RC performance in standardized tests of L2 readers tend to be lower than their real proficiency, which underestimates their real L2 abilities (Service & Craik, 1993). Due to the L2 readers’ tendency for excessive surface comprehension and the reading difficulty of the adopted four reading passages, the comprehension test in this study might be able to measure participants’ ability to read literally but did not sufficiently measure participants’ inferential comprehension abilities.

The fourth limitation is about participants’ language proficiency

Chances are less proficient FL readers make reading inference which is not well supported by clues from the reading. Moreover, studies have shown that poor L2 inferential RC stemming from less adequate language proficiency would weak and deteriorate the influence of WM on reading comprehension performance (Clarke, 1980). In that case, readers would mostly engage excessively on surface or propositional-level understanding, such as syntactic parsing or lexical decoding, and have few available cognitive resources to retrieve relevant LTM knowledge.

According to research (Alptekin & Ercetin, 2009; Chun & Payne, 2004; Horiba, 1996, 2000; Taillefer, 1996), without proper guidance and reading instruction including reading strategies, at early stage of learning English L2 readers tend to perform like inefficient L1 readers and would highly likely fail to make higher-level conceptual processing in reading. A collection of studies have suggested that proficiency levels may moderate the advantage of processing information more efficiently for those with higher WMC (Linck, Osthus, Koeth & Bunting, 2014). For example, low-proficiency bilinguals with greater WM spans performed significantly better than those with lower span scores on tasks addressing L2 processing abilities (Abu-Rabia, 2001; Hummel, 2009; Leeser, 2007; Linck, Hoshino, and Kroll, 2008; Weissheimer & Mota, 2009). However, when examining highly proficient bilinguals, several studies failed to show significant L2 processing advantages for individuals with higher WM scores (Fehringer & Fry, 2007; Foote, 2011; Hummel, 2009). Therefore language proficiency and background knowledge about language itself and reading texts might dilute the power of WM-on RC.

The fifth limitation is the validity or the generalization power of one single test

Language teachers need to know that individuals can be strong in one aspect and less strong in another. Thus, results of one single language test cannot account for students' overall language ability. To fully measure RC ability, various types of comprehension questions and test designs would helpfully assess multi-level skills in reading. Most research designs of previous studies about WM and RC have the similar research procedure to mine: to correlate the outcome of WM to the performance of RC. However, some studies following the procedure did not testify the significant correlation between WM and RC (Chun, 2002; Zhou, 2002). Some thesis studies also found it hard to relate WM to RC. In my opinion, future studies should involve more important variables in studies beside WM, such as readers' reading skills, and background knowledge.

Pedagogical Implication

Educators and researchers in cognition and brain science have been extremely interested in investigating how humans learn. When one learns, he or she gain new information and maintain old one. How one learns is vital to the long-term objectives in education. One of the primary research areas in cognition is memory. "Working Memory" is defined as a general ability for individuals to hold information in mind and to mentally manipulate new and old knowledge over a short period of time. WM does not refer to the scope or size of one's memory. It is thought as a mental workspace that individuals use to process and store information. Literature reviews suggest that WM is quite essential for learning at school, such as doing mental arithmetic, following teachers' instruction or reading comprehension. Though this current study was not able to duplicate the influence of WM on inferential RC due to some limitations mentioned above, there are still some pedagogical implications suggested by the results.

The results of the current studies indicated that L2 WMC had no influence on L2 literal and inferential RC whether L2 WMC was measured with a recall-RST or a recognition-RST. However, literature suggests that L2 WMC was not correlated to L2 literal comprehension but strongly correlated to L2 inferential comprehension (Altepkin & Ercetin, 2010; Anderson et al., 1996; Baddeley, 2012; Conway & Engle, 1994; Daneman & Hannon, 2007; Miyake & Friedman, 1998). Also the recall-RST would be able to demonstrate participants' WMC better than the recognition-RST. Though the result of the current study turned out different from previous studies, important variables were found to be influential in the literature review of the discussion section when it comes to L2 WMC and L2 RC.

The important implication deduced from the current study was that the performance of readers' comprehension depends not only on their WMC but also on other factors, such as reading skills and background knowledge (Daneman & Carpenter, 1980; Ericsson & Kintsch, 1995). This informs teachers that RC is a complicated task which requires many cognitive processes and skills. In teaching, instructors or language teachers should expand the courses beyond one single component skill. Though numerous studies support the predictive power of L2 WM on demanding cognitive tasks, the present study implied that L2 WM is only one factor of the contributions to readers' comprehension. WMC might carry great influence on demanding cognitive tasks as literature suggested, and language instruction might consider including course of training language learners' abilities to manipulate new and old information and to synthesize thorough comprehension.

Since WMC is only one of the contributions to language comprehension as the result indicated, language teachers should present their courses in a wide variety of teaching methods. Reading skills, background knowledge, techniques to maintain attention to tasks and also linguistic use and usage might greatly help readers to comprehend texts. In other words, the result of the current study did not show testimony the power of WMC; however, it implied the complexity of language comprehension. In teaching, the instructors should enrich the curriculum as much as possible so as to boost readers' potential of being fluent readers to the best.

Suggestions for Future Studies

This study was to scrutinize the interaction between L2 readers' ability to understand given text and their WMC ability to manipulate information. WMC could be seen as the strength and power of L2 readers' brain—L2 WM. Baddeley (2012) proposes the WMC theory as a fascinating solution for it acts like a compensation for individuals' inadequate competence: when one masters the skills of high-WMC readers to be able to efficiently complete tasks, one's performance would excel his or her original competence. However, obviously one single study, like the current study, is not adequate to duplicate the robust relationship between L2 WMC and L2 inferential comprehension which numerous studies have supported. More research and more well-designed research should be done so as to inform English teachers of the benefits WMC could do for the language learners and assist readers in possible ways. Based on the discussion and limitation mentioned above, suggestions for future studies are as follows.

First of all, with regards to independent variables, future studies could involve variables of readers' background knowledge and reading skills as independent variables (Daneman & Carpenter, 1980; Ericsson & Kintsch, 1995). So should readers' attention to tasks at hand (Engle et at., 1999). The results of this study suggested that WM was not a stable trait which individuals possess anytime in any cognitive task. It also suggested that it is difficult and not easy to relate WMC to inferential RC. Variables, such as readers' background knowledge, reading skills and attention to tasks are also essential for studies of investigating WMC and inferential RC. Beside the independent variable of WM, readers' background knowledge about texts is essential in the outcome of RC. Future studies could establish a data base of RC tests in order to design proper RC test based on participants' language proficiency. Future study should also include reading texts and comprehension questions which are appropriate for participants' language level. When testifying the power of WMC with participants, future study could consider involve those participants who have similar language competence in reading skills and background knowledge. Future studies could also use pilot studies with other participants of similar language levels and commitment to studies in order to establish valid research measurements of RST and RC. The target participants could be given language courses about reading skills and background knowledge about text structure and domain knowledge.

Secondly, with regards to the characteristics of participants, their language levels and attention to tasks could severely influence the result of studies and hence mask the true influence of independent variables. It is difficult to foresee how attentive and committed participants would perform during the research process. Hence the result of outliers should be eliminated. Thus there should be more participants should be involved so as to adequate data for further analysis if the results of outliers were to be eliminated.

Also, with regards to the research procedure, I propose that adequate responding time must be available for participants to comprehend the given RC tests. Participants should be given adequate time in comprehending the text—decoding the information and integrating new and old messages. By doing so their true ability to comprehend texts literally and inferentially would be assessed. Besides adequate time for responding to RC questions, future studies could broaden the time of conducting research into the whole semester or school year. Instead of adopting one-time procedure like numerous previous studies do. The longitudinal survey would repeatedly observe the correlation among the variables, participants' WMC, reading skills, background knowledge, attention and their RC performances. By doing so, the result of participants' WMC and ability to make reading inferences would be more accurate.

The research procedure should also consider the feasibility of conducting the research. The feasibility of conduction research designs should be the top priority of completing theses. As a teacher in service, little resources were available for me. As mentioned in the limitation section, in this study the number of participants with similar language competence is inadequate for quantity analysis. I had no choice but to adopt a convenient sample of six classes. In the phase of designing this research, I struggled in the tug of war between sample sizes and participants' language abilities. In the long run, I chose to maximize the sample size as much as possible, optimistically expecting that the larger number of participants would satisfy the quantitative analysis. The mistake I made here was the assumption that the individual differences, such as varying language proficiency and performance, would be canceled. My attention was devoted to duplicating the influence of WM on RC, in which I not only neglected the quality and sample size of participants but also the need to include more independent variables.

Last but not least, future studies should also consider the lack of stability of WM. WMC changes from task to task as mentioned in the limitation section. The research design would be much more thorough if the study would be able to assess participants' WMC exactly during the time they took RC test, not the WMC when they took the RST. Otherwise the future studies should try to ensure that the participants have the same or similar WMC in both RST and RC test. Or the future studies could administrate the training of WMC to boost readers' WMC and their ability to manipulate and store information while taking tasks or completing RC test. This way of instruction intervention might reflect the improvement curve and the correlation patterns between WM and learning performance. In the field of WM and RC, some research testifies the power of WM through research designs of instruction invention (Berninger, 1999; Wolf & Katzir-Cohen, 2001). Instructors or teachers exploit a certain sessions of courses for WM training in order to improve students' WM. Afterwards students' abilities to make literal and inferential comprehension, are tested and monitored to see how learners' RC and WMC improve through the whole session. In this case RC tests might not fully assess participants' ability to comprehend, observation journals might be included.

In sum, when investigating the power of WM on RC, future studies should involve more relevant variables than participants' WM: RC, reading skills, the difficulty levels of RC tests and their background knowledge. The correlation between WM of that RC test and their performance of that RC test would be more precise than separating the tests of WM and RC.

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APPENDIX A

RST—LIST OF RST STIMULUS SENTENCES

He played baseball all day at the park and got a sore arm.

The clerk in the department store put the presents in a bag.

I saw a child and her father near the river playing ball.

His younger brother played guitar in a rock and roll band.

Suddenly the taxi opened its door in front of the bank.

The last thing he did was to take a nice hot bath.

Her best memory of England was the Tower of London bell.

At the very top of the tall tree sat a small bird.

She took a deep breath and reached into the rusty box.

The state of Wisconsin is famous for its butter and cheese.

He overslept and missed all the morning economics class.

The first thing he does every morning is swing a golf club.

Popular foods in the summer are watermelon and sweet corn.

The boy was surprised to learn that milk came from a cow.

The only thing left in the kitchen cupboard was a broken cup.

The birthday party began in the morning and lasted all day.

The young woman and her boyfriend thought they saw a dog.

There was nothing left to do except leave and lock the door.

In order to attend the dinner she needed to buy a dress.

The woman screamed and slapped the old man in the face.

She leaned over the candle and her hair caught on fire.

The drinks were all gone and all that remains was the food.

He quickly drank some of the milk and then washed the glass.

He looked across the room and saw a person holding a gun.

The hunting knife was so sharp that it cut his right hand.

She soon realized that the man forgot to leave the room key.

The saw that he brought was not strong enough for the lock.

The first driver out in the morning always picked up the mail.

All that remained in the lunch box was one salted nut.

The boat engine would not run because it was out of oil.

It was a very simple meal of salted fish and boiled rice.

They decided to take an afternoon break by the large rock.

He wanted to leave his bags and jackets in the hotel room.

There were so many people that I couldn't find a seat.

He opened the bottom drawer and pulled out a shirt.

The skiing was so wonderful that he didn't mind the snow.

They knew that it was impolite to eat spaghetti with a spoon.

The season that people often associate with love is spring.

The letter was lost because it did not have a postage stamp.

The people in northern Europe always like to travel by train.

All morning the two children sat and talked under a tree.

At night the prisoners escaped through a hole in the wall.

APPENDIX B

The Reading Comprehension Test with Four Passages Applied in the Study

1 Forever Takes a Bow(鞠躬)

Actor Nathan Lang, years old, died in his sleep last night in his house. Nathan Lang started his acting life in the 1970s. He was most known for (因..而眾所皆知) playing Justin Maud in Young Hours. The movie made the world swoon over him. Women wanted a husband like him; men wanted a brother like him. Forever Justin, his fans called him. After Young Hours, Nathan Lang was seen in several big movies: Fallen, After Tonight, and Killing Jules. The last one won him a best actor award. In the 1980s, Nathan Lang lost his shine(失去魅力) on the big screen. During this time, his movies never entered the top 20 list. Nathan Lang's last movie was *Dreams*. Though the movie won him two actor awards, it did not bring his fans back to the theater.

This Saturday morning, 10 o'clock at St. Peter's Church, there will be a "movie party," as Lang wished. Friends and family will get together and enjoy once again the good times he brought to the world.

rise and fall 人生起伏
show business 演藝事業
deal with 處理

1. (C) What is this reading mostly about?

(A)Nathan Lang's love and hate for his family.

(B)The good and bad about Nathan Lang's movies.

(C)The rise and fall of Nathan Lang in show business.

(D)Nathan Lang's life before and after he became an actor.

[inferential comprehension]

2. (B) What does swoon over mean in the reading?

(A)Close the door on. (B)Go crazy about.

(C)Share the joy with. (D)Try hard to deal with. *[literal comprehension]*

3. (C) Here are reviews about Nathan Lang's movies (電影賞析). From the reading, which is most likely (最有可能) a review for *Dreams*?

(A)…nothing new in the story; Nathan Lang clearly didn't do enough homework about his part in the movie. It was no surprise that the movie didn't make it into to 10 list (沒辦法進前 10 名)the first week it was out…

(B)…it became Nathan Lang's second best-selling movie (票房第二好的電影) and also this year's third best-selling movie in the country and may even get him another best actor award(最佳演員獎)…

(C)…see him not as the actor Nathan Lang anymore but as the poor old man in the movie. However, goof acting does not always help with the ticket sales (票房銷售)…

(D)…the story is fresh and interesting (新鮮有趣), but the acting is not. However, it has been the country's best-selling movie for the past three weeks. Clearly Nathan Lang's fans cares less (較不在乎) about his acting than his handsome face…

[inferential comprehension]

2 **Below is what Josie wrote in her notebook.**

Dec. 15

A very sad day. A school bus was hit (被撞) by a truck. Many kids were bally hurt (嚴重受傷). A Little boy lost his life. His mom was the kid's teacher. We couldn't bring her back, either.

Dec. 22

Lonnie said she'll wear all white to the Christmas party. I said she's lost her mind (瘋了). We wear white all the time. Who would still want to wear white on Christmas Eve?

Dec. 25

People kept coming in and asked for our help because they got hurt. Why do people always do stupid things on holidays?

Dec. 31

The police brought in a young man who broke his leg when he was trying to enter a house. When taking care of his leg, I asked him why he wanted to enter another person's house, and he said he just wanted to borrow a pot (鍋子). But Officer Clarke said he's been borrowing many pots from strangers' houses.

Jan. 3

I knew my lunchtime was over when Howell came to my table. He's a nice guy. But now many heads he's cut open is the last thing I'd want to know when I'm eating beef sandwiches.

4. (B) Where does Josie work?

(A)In a school. (B)In a hospital.

(C)In a restaurant. (D)In a police station.

[inferential comprehension]

5. (B) Which is true about Josie?

(A)She did not work on Christmas because she got hurt.

(B)She does not like what Howell talks about at lunchtime.

(C)She lost her little boy when the school bus was hit by a truck.

(D)She liked Lonnie's idea about what to wear for the Christmas party.

[literal comprehension]

6. (D) What do we know from the reading?

(A)The truck driver who hit the school bus died.

(B)Howell loves to have beef sandwiches for lunch.

(C)Lonnie did not want to go to the Christmas party with Josie.

(D)Officer Clarke did not think what the young man said was true.

[literal comprehension]

3

Here is this year's report on the Top Ten (前十大) Cities of Animal Island by *Best Living.Com*.

①**Goosetown**：Climbing up from last year's second place, Goosetown comes in first for its lovely(可愛的) parks, cultural centers (文化中心), and comfortable living space.

②**Tigerville**：Losing its top place to Goosetown, Tigerville is still a beautiful city, and as green as ever.

③**Duckland**：The only city staying in our top three for five years, Duckland is now cleaning itself up for next year's Football World Cup.

④**Oxtown**：Not just a famous business city, Oxtown has turned itself into a garden city.

⑤**Lionville**：Famous for its culture (文化) and beautiful gardens, Lionwille is the first city in the north (北) to enter our top five.

⑥**Sharkville**：With winter sports as good as Oxtown's, this exciting city is our second best pick in the east (東).

⑦**Foxland**：This city with thite beaches could rise higher in the rankings(排行) if there were fewer traffic problems (交通問題).

⑧**Goatville**：Dropping two places, Goatville should now think more about parks than shopping centers.

⑨**Turtleland**：New in our top ten, this old fishing town is full of surprises.

⑩**Cowtown**：Dropping from number seven, Cowtown must clean up the air (淨化空氣).

7.(D) What is NOT true about the report?

(A)It tells us what some cities are known for.

(B)It tells us what some cities need to deal with.

(C)Green space plays an important part in the report.

(D)It is the second year the *Best Living.Com* did the report.

[literal comprehension]

8. (A) What can we learn about the cities in the report?

(A)One city in this year's top five is in the east.

(B)Few people come to Oxtown to do business.

(C)No city in the north entered this year's top ten.

(D)Goosetown is Animal Island's second biggest (第二大的)city.

[literal comprehension]

9. (D) Which is the most likely ranking of LAST year's top ten cities of Animal Island?

(A)①Tigerville ②Goosetown ③Cowtown ④Oxtown ⑤Duckland

⑥Goatville ⑦Lionville ⑧Sharkville ⑨Foxland ⑩Turtleland

(B)①Tigerville ②Goosetown ③Duckland ④Beartown ⑤Lionville

⑥Sharkville ⑦Goatville ⑧Cowtown ⑨Foxland ⑩Oxtown

(C)①Goosetown②Tigerville ③Duckland ④Foxland ⑤Beartown

⑥Goatville ⑦Cowtown ⑧Lionville ⑨Oxtown ⑩Sharkville

(D)①Tigerville ②Goosetown ③Duckland ④Oxtown ⑤Beartown

⑥Goatville ⑦Cowtown ⑧Lionville ⑨Foxland ⑩Sharkville

[inferential comprehension]

4

Six people are being interviewed about the garden on the roof of their building.

Jasmine：I loved the idea when Wilber first told me about it. We had lots of meetings with our neighbors (鄰居), trying to make them understand why it's good to build a garden on the roof. Now people love coming here, and it's helped many of us become friends!

Wilber：The whole thing wasn't easy at first. But Jasmine helped a lot. And she was really good at making people happy to give money for the roof (屋頂) garden.

David：My kids love going up there. They sit there watching butterflies and birds. The roof garden brings them closer to nature.

Samuel：You want something green? Visit the park! It's only one block away! After the roof garden was build, bugs started flying into my apartment! And the kids leave mud (留下泥巴) on the stairs (樓梯) when they come down from the roof!

Rosie：Our buildings is now cooler in the summer. My baby sleeps well even on hot summer days!

Flora：Guess where these tomatoes are from! Not from the supermarket. They're from our roof! Isn't that wonderful?

10. (B)Which of the good things about the roof garden is **NOT talked about** (沒有說到) in the interview?

(A)It brings people in the building closer (更親近) together.

(B)It uses the rainwater that falls on the top of the building.

(C)It makes the building a more comfortable place during summer.

(D)It gives people in the building a chance to grow (種植) their own food.

[inferential comprehension]