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<th>Contributions of executive processing to reading comprehension: bilinguals in Hong Kong</th>
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<td>Author(s)</td>
<td>Chan, Pak Hong Gabriel (陳栢匡)</td>
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<tr>
<td>Citation</td>
<td>Chan, P. H. G. (2014). Contributions of executive processing to reading comprehension: bilinguals in Hong Kong (Outstanding Academic Papers by Students (OAPS)). Retrieved from City University of Hong Kong, CityU Institutional Repository.</td>
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<tr>
<td>Issue Date</td>
<td>2014</td>
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<td>URL</td>
<td><a href="http://hdl.handle.net/2031/7518">http://hdl.handle.net/2031/7518</a></td>
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Contributions of Executive Processing to Reading Comprehension:

Bilinguals in Hong Kong

A Report Submitted to

Department of Applied Social Studies

in Partial Fulfillment of the Requirements

the Bachelor of Social Sciences in Psychology

by

CHAN Pak Hong, Gabriel

April 2014
Abstract

Although the relation between executive process and reading comprehension is well-supported by bilinguals with languages all over the world, it may not be the case in Chinese especially for bilinguals in Hong Kong. In addition, cross language transfers were argued to appear in first language (L1) and second language (L2) linguistically similar to each other. With linguistically different orthography and phonology between Chinese and English, current study addressed two questions: 1, how executive process within the system of working memory contributes to performance of reading comprehension; 2, the possibility of cross language transfer between working memory and reading comprehension. To in-depth analyze the effect of working memory to reading comprehension, a measure of suppressing ability was further conducted. The studies recruited 46 adult bilinguals in Hong Kong and achieved following findings: 1, L2 working memory significantly predicts L1 reading comprehension; 2, L1 working memory is able to predict general performance of irrelevance suppression in both L1 and L2. Current exploratory findings support verbally shared nature of working memory across languages and demonstrate cross language transfer among adult bilinguals in Hong Kong, possessing highly different L1 and L2.

Keywords: executive process, reading comprehension, working memory, bilingual
Acknowledgements

The research was supported by a grant from the City University of Hong Kong Idea Incubator Scheme funded to Dr. Bonnie Wing-Yin Chow (Project number: 6987022).

I am grateful to Dr. Bonnie Wing-Yin Chow, for her generous and insightful supervision over the research.
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Chapter 1

1. INTRODUCTION AND LITERATURE REVIEW

1.1. General Introduction

Working memory (WM) is defined as the ability to keep information while processing them according to cognitive needs. The ability could be applied to various tasks such as mathematics, visual-spatial location and language. Among the tasks, language ability is widely recognized to relate to WM. Reading and listening tasks are especially studied more than writing and speaking tasks with WM due to the functions and property of phonological loop, a component responsible for verbal information processing in the model of working memory.

The Model of Working Memory was initially contended by Baddeley and Hitch (1974), attempted to exemplify conceptual cognition coping with informational input. The model is consisted of three main components. Central Executive was proposed as the organizer and coordinator of cognitive resources on the basis of concurrent need. Under the supervision of central executive, two slave systems are responsible for two important tasks respectively. Phonological loop was described to deal with linguistic input from different sensory modalities, while visual-spatial sketchpad deals with pictorial pattern and spatial information. In accordance with the model, reading and listening ability were dependent on phonological loop, which attract interest in investigation of the relation between the two (Baddeley & Logie, 1999).
Most people in Hong Kong have Chinese as a first language (L1) and acquire English as a second language (L2). With cultural and historical factors taken place, educational emphasis creates bilingual development among people in Hong Kong (Gottardo, Chiappe, Yan, Siegel, & Gu, 2006; Zhong, McBride-Chang, & Ho, 2002). The study thereby included people in Hong Kong to find out interactions between WM and reading comprehension with bilinguals in Hong Kong. Reading comprehension is related to WM (Cantor & Engle, 1993; Daneman & Carpenter, 1980; Kolić-Vehovec & Bajšanski, 2007; Masson & Miller, 1983; Proctor, Silverman, Harring, & Montecillo, 2012; Rupp, Ferne, & Choi, 2006). It consists of a series cognitive process for acquisition of meanings over sentences, paragraph and whole passage. The underlying analyses take place by integration, combining phrases and clauses in the text and existing world knowledge; inference, conducting logical analysis to establish semantic coherence; suppression, putting irrelevant or distracting information aside to prevent confusion and error of intrusion, as well as other processes making use of WM (Daneman & Carpenter, 1980).

1.2. General Relation between WM and Reading Comprehension

In western literatures, there have been strong evidences indicating WM’s predictive ability of reading comprehension. A large number of studies documented the relation between WM and reading comprehension, including those countries located in Asia and Europe. (Cain, Oakhill, & Bryant, 2004; Christmann, & Groeben, 2008; Kondo, Morishita, Ashida, Otsuka &
Given a rich combination of studies in a meta-analysis (Daneman & Merikle, 1996), a confident claim was made as a support of the predictive power of WM over language comprehension.

1.3. L1 Working Memory and L1 Reading Comprehension

Considering Chinese as L1 among individuals in Hong Kong, studies found that verbal WM is related to level of text comprehension. A study aimed to investigate the contribution of verbal WM and Chinese text comprehension (Leong, Tse, Loh, & Hau, 2008). The construct of Chinese verbal WM composed of memory span and tongue twister tasks was measured collectively with performance of reading comprehension tasks in four passages. Other reading-related variables such as pseudoword reading and rapid automatized naming (RAN) were collected from 518 children in Hong Kong at the level of primary education. Result recommended that a large portion of variance in text comprehensive performance was explained by Chinese verbal WM, congruent with previous research in western world.

Another study revised the model of reading comprehension with 248 Chinese at fourth grade in Hong Kong (Yeung, Ho, Chan, Chung, & Wong, 2013). RAN, morphological awareness, syntactic skills, verbal WM and other skills were measured. Syntactic skills,
discourse skills and verbal WM predict reading comprehension with word reading under controlled. What is worth noticed is that Chinese verbal WM shares the least amount of variance on reading comprehension, which is one of the reasons why current study further explores the relation between relation between verbal WM and reading comprehension in Chinese context.

Another study controlled word reading and found the inability of verbal WM to predict reading comprehension (Chik et al., 2012). The inconsistency of result urge for clarification on the effect of Chinese verbal WM.

1.4. L2 Working Memory and L2 Reading Comprehension

Strong connection was found between English verbal WM and English reading comprehension in L2 domain (Lipka & Siegel, 2010; Low & Siegel, 2005). A study with 43 participants in Turkey aimed to find out the relations of WM capacity and L2 reading comprehension (Alptekin & Erçetin, 2010). In general, WM has been found to be a robust factor predicting L2 comprehension as indicated in a meta-analysis with an estimate of effect size ($p$) = .255 in overall population (Linck, Osthus, Koeth, & Bunting, 2013).

A review in a Japanese study was conducted under a L1 background with more varied orthography and phonology comparing to English. Japanese participants were recruited for performance examination of Reading Span Task (RST) (Osaka & Osaka, 1992). A correlational analysis was conducted with scores of TOEFL reading category and performance of
a cloze test with 350 words. Significance was discovered in the relation between RST and TOEFL reading score, supporting transfer from L2 WM to L2 reading performance despite different language characteristics.

1.5. Working Memory and Reading Comprehension – Cross Language Effect

Cross-language transfer is debatable. Research found that transfer occurs on condition that L1 and L2 linguistic characteristics are similar to each other. A possibility is that verbal WM is shaped and adjusted according to language demand. Indeed, studies evaluate WM and other reading skills substantiate this claim with significant findings in alphabetical languages. A Japanese study with 35 college students supports this proposition with no effect found between L1 WM and L2 comprehensive tasks like Pragmatic Listening Test and Lexical Access Test, which assessed one’s ability to comprehend underlying intention and how quickly a semantic extraction could be made (Taguchi, 2008).

However, there are empirical discoveries argued against the assertion. For instance, a study measuring reading skills including word reading, RAN, phonological and orthographical identification suggested multiple cross language transfers among the skills (Keung & Ho, 2009). Findings such as interrelation between phonological awareness and RAN in L1 and L2, and predictability of L1 orthographical skills over L2 word reading revealed that it is possible to have cross language effect in reading domain even in two phonologically and orthographical varied
languages. Furthermore, the result of a longitudinal study monitored reading development of 141 children in Hong Kong for two years (Li, McBride-Chang, Wong, & Shu, 2012) shows that spelling and reading comprehension are correlated across two languages. Above evidences favor for cross language effect at a lower level of reading tasks involving cognitive skills.

1.6. Adult Bilingual Sampling

Previous studies mostly selected child as the target in research of reading skills and relevant variables (Goff et al., 2005; Zhong et al., 2002). One of the drawbacks in collecting data from children is their test performance are developmentally limited. Both cognitive abilities and reading experiences are fairly constrained. It is therefore unlikely to find sufficient information and to draw summary over reading capability in other life stages (Hu, 2008). On the other hand, some studies adopted adults and college students with unstable L2 representation background such as those who participated in English accelerating courses. The advantages or deficits of cognitive ability and reading skills cannot be fully justified by bilingualism (Li, 2008). Even though the participants have mastered English as certified by international qualifications, the degree of attribution to established representation of L1 and concurrent cognitive ability, and how does L2 contribute to language development are questionable. Current study addresses above sampling issues by recruiting young adults in Hong Kong and explores influence from bilingualism to comprehensive analysis during reading.
2. STUDY 1

2.1. Research Question and Hypotheses

Present study aimed to explore interactions among WM and reading comprehension in bilinguals. In accordance with literature review, (1) within language relation was expected to be discovered between L1 WM and L1 reading comprehension as well as L2 between WM and L2 reading comprehension. Relations were expected to be found across languages in forms of (2) L1 WM – L2 reading comprehension and (3) L2 WM – L1 reading comprehension.
2.2. Methodology

2.2.1. Participants

The sample was recruited from an introductory class of Psychology, from which fulfilling course credit requirement. 46 local undergraduates and postgraduates (17 males, 29 females) aged 19 – 47 years (mean age: 24.11). Criteria of bilingual were set to be using L1 in any form at home and most daily communication, and have been Cantonese-speaking individuals who learn English as second language (ESL).

2.2.2. Materials and Procedures

Prior to any tests, a consent form was given to participants (see Appendix A) for agreement of the study. Demographic information was collected by a test form providing space for participants to fill out their test answers (see Appendix B). All the participants were evaluated with a series of test as following indicated, particularly for test of nonverbal intelligence and tests of phonological short-term memory in two languages as controlled. There were two reading comprehension tasks, two verbal WM tasks and one spatial WM task. The medium of instruction is Cantonese except for tasks in English versions. Of the above tasks, reading comprehension and verbal WM were tested in respective languages.
**Raven’s standard progressive matrices.** Raven’s progressive matrices was used to measure one’s non-verbal intelligence (Raven, 1938), which plays as a controlled variable commonly related to reading tasks. Five sets of matrices were designed in a standard version. Each set consists of 12 multiple choice questions that required participants to answer out of eight provided choices on the basis of logical inference from 2x2 and 3x3 matrices. The test is progressive difficult from set A to set E that is suitable to be administered from children at five years of age to the elderly. In current study, only set D and set E were adopted in accordance with the level of difficulty to sample consisted of adults. Each correct answer scores for one mark. The total score is 24, with Cronbach’s α .77.

**English reading comprehension.** Three passages about 850 words each in average were chosen from the website http://www.howstuffworks.com. Issues over science, economics and culture are discussed respectively in each passage (see Appendix C). Participants were given 20 minutes to finish 15 MC questions and write their answers on a test form provided. No writing on the testing material is allowed to control possible confound from reading skills. The highest mark for this task is 15, Cronbach’s α is .49.

**Chinese reading comprehension.** The test consists of three passages from old newspapers [men mei po] in 2000 and 2001. There are around 1000 characters per article with 15 multiple choice questions devised based on the passages discussing social problems in Hong Kong (see Appendix D). Comprehension level for each passage is tested with five questions.
Participants are required to choose from choices offered and write them on a paper within 20 minutes. No writing on the testing material is allowed to control possible confound from reading skills. Out of the same consideration in the Chinese version, no writing on the testing material is allowed. The highest mark for this task is 15, Cronbach’s $\alpha$ indicates reliability as .61.

**English comprehensive test of phonological processing (CTOPP).** Participants were required to report a set of non-words immediately after playing the recording for a set of non-words (Wagner, Torgesen, & Rashotte, 1999). There were 18 sets that consisted of at least one to the most seven compounds in a set. Scores were given to accurate pronunciation and congruity between reporting order and recording order. The order mark is given when two non-words were reported in the same order as the recording. No score of ordering is given to only one non-word. However, one score would be deducted if there is any non-word pronounced more than the concurrent recording. Total marks for the test is 108, with Cronbach’s $\alpha$ in .63.

**Chinese comprehensive test of phonological processing (CTOPP).** The Chinese version of CTOPP takes the same format from English version (Wagner et al., 1999). The test asked participants to report Chinese characters in the same tonal frequency accurately according to the presenting order. There are eight blocks ranging from five to twelve characters. The blocks were presented and reported in increasing manner. Marks are given to reading accuracy and reporting correctness from which total marks are 128, with Cronbach’s $\alpha$ in .71.
**Auditory working memory – English.** A set of words and single digit numbers was randomly read out and participants were asked to report them in the order of ‘first words, then numbers’ (Woodcock, McGrew, & Mather, 2001). Reporting orders in words and numbers also have to comply with the original sequence. The materials and arrangement were preset in the Woodcock test of auditory WM. There were six blocks with items ranging from three to eight in any combinations of word and number for a trial. Each block is consisted of three trials and there were 18 trials in total. The test starts with the block of three items and continues in ascending order. The task was terminated when participants gained no mark from a group of six trials. Score was given to each correct order of word and number presentation in trials. Thus, the maximal mark of a trial is two and total mark for all trials is 36. Cronbach’s α is .61.

**Auditory working memory – Cantonese.** The exact procedure was adopted from the same format in English version (Woodcock et al., 2001). Self-devised Chinese words and single digit numbers were randomly arranged. Participants were requested to repeat what they heard in the order of ‘first words, then numbers’ while maintaining heard sequence of words and numbers. All the materials were read in Cantonese. Following the same design in the English version, there were 36 trials divided into six blocks with three to eight items of different combinations. Similarly, this test starts with a block of the least items and proceeds to blocks with more and more items. There is no cut off point in order to capture the whole picture of
report. Two points was granted in a trial on conditions of a correct order in words and numbers respectively. Cronbach’s α is .69.

Chinese words were selected on simplicity and avoidance of homophonic pronunciation with numbers. Each word was consisted of two Chinese characters pronounced with two phonemes, while single digit number in Chinese was pronounced with one phoneme. The measures prevent possible influence to score accuracy from phonemic priming and encoding ambiguity.

**Spatial relation.** A series of visual pattern were given to participants to assess visual-spatial ability (Woodcock et al., 2001). A composite picture consisted of two or three pieces was presented. The task requires participants to identify fragments that build the composite. The task was terminated when the score does not achieve the standard of a section. There are 81 trials in total and two cut-offs were distributed at 10 and 56 points. A correct item was scored for one point. Cronbach’s α is .73.
2.3. Results

Means and standard deviations of demographics and reading variables are listed in table 1. Correlational analysis was conducted to detect the relations among cognitive abilities and performance in reading comprehension. Regression analysis was used to confirm the predictive nature of variables.

Table 1

*Descriptive Statistics of Demographics And Reading Related Tests*

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<thead>
<tr>
<th>Variables</th>
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<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
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<td></td>
</tr>
<tr>
<td>Age</td>
<td>24.11</td>
<td>6.43</td>
</tr>
<tr>
<td>Years of Studying Chinese</td>
<td>20.82</td>
<td>5.73</td>
</tr>
<tr>
<td>Years of Studying English</td>
<td>20.00</td>
<td>6.12</td>
</tr>
<tr>
<td>Reading Variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raven’s Progressive Matrices</td>
<td>19.91</td>
<td>3.03</td>
</tr>
<tr>
<td>L1 Reading Comprehension</td>
<td>6.09</td>
<td>1.87</td>
</tr>
<tr>
<td>L1 Working Memory</td>
<td>23.39</td>
<td>3.47</td>
</tr>
<tr>
<td>L1 CTOPP</td>
<td>75.33</td>
<td>12.55</td>
</tr>
<tr>
<td>L2 Reading Comprehension</td>
<td>10.5</td>
<td>2.00</td>
</tr>
<tr>
<td>L2 Working Memory</td>
<td>17.7</td>
<td>3.20</td>
</tr>
<tr>
<td>L2 CTOPP</td>
<td>93.67</td>
<td>10.52</td>
</tr>
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</table>
Within language effect was found between WM and reading comprehension in neither L1 nor L2 (see Table 2). Relation between L1 WM and reading comprehension was not significant, $r(44) = .11$, $p > .05$. The same relation in L2 was not significant, $r(44) = -.17$, $p > .05$. 
Table 2

Correlations of Demographics and Reading Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>1. Age</td>
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<td></td>
<td></td>
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<tr>
<td>2. Years of Studying Chinese</td>
<td></td>
<td>.83*</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Years of Studying English</td>
<td></td>
<td></td>
<td>.92*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4. Raven’s Progressive Matrices</td>
<td></td>
<td>.09</td>
<td>.01</td>
<td>.04</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>5. L1 Reading Comprehension</td>
<td></td>
<td>-.23</td>
<td>-.17</td>
<td>-.20</td>
<td>.35*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. L1 Working Memory</td>
<td></td>
<td>-.20</td>
<td>-.06</td>
<td>-.08</td>
<td>.02</td>
<td>.11</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. L1 Short-term Memory</td>
<td></td>
<td>-.11</td>
<td>-.01</td>
<td>-.11</td>
<td>.01</td>
<td>.00</td>
<td>.37*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. L2 Reading Comprehension</td>
<td></td>
<td>.15</td>
<td>.25</td>
<td>.23</td>
<td>.26</td>
<td>-.18</td>
<td>.03</td>
<td>.02</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9. L2 Working Memory</td>
<td></td>
<td>-.01</td>
<td>-.15</td>
<td>-.03</td>
<td>-.06</td>
<td>.33*</td>
<td>.26</td>
<td>.29*</td>
<td>-.17</td>
<td>1</td>
</tr>
<tr>
<td>10. L2 Short-term Memory</td>
<td></td>
<td>-.43*</td>
<td>-.37*</td>
<td>-.33*</td>
<td>.10</td>
<td>.08</td>
<td>.36*</td>
<td>.33*</td>
<td>-.03</td>
<td>.26</td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .01*
No cross language relation was found between L1 WM and L2 reading comprehension, \( r(44) = .03, p > .05 \). Surprisingly, L2 WM significantly related to L1 reading comprehension, \( r(44) = .33, p < .05 \). Regression analysis suggested a significant prediction from L2 WM to L1 reading comprehension after controlling nonverbal intelligence, \( \beta = .36, t(45) = 2.67, p < .05 \). (see Table 3). L2 WM explained significant variance in L1 reading comprehension, \( R^2 = .25, F(2, 43) = 6.97, p < .01 \).

Table 3

Regression Statistics of L2 Working Memory Predicting L1 Reading Comprehension

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model ( R^2 )</th>
<th>( B )</th>
<th>SE ( B )</th>
<th>( \beta )</th>
<th>( t )</th>
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<tr>
<td>Step 1</td>
<td></td>
<td>.12</td>
<td></td>
<td></td>
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<tr>
<td>Raven</td>
<td></td>
<td>.16</td>
<td>.07</td>
<td>.35</td>
<td>2.44*</td>
</tr>
<tr>
<td>Step 2</td>
<td>.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raven</td>
<td>.17</td>
<td>.06</td>
<td>.37</td>
<td>2.77**</td>
<td></td>
</tr>
<tr>
<td>L2 Working Memory</td>
<td>.15</td>
<td>.06</td>
<td>.36</td>
<td>2.67*</td>
<td></td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .01*
2.4. Discussion

The study investigated cross-language transfer in bilingual perspective and WM contributes to reading comprehension in hierarchal order: from WM then suppressing ability of central executive to reading comprehension. Three hypotheses were formulated to confirm the effect from verbal WM to reading comprehension. Although there were no relations found, previous research and theoretical possibilities were discussed.

The first hypothesis is rejected with no within-language relations found between WM and reading comprehension. There are a few explanations for this unexpected result comparing with previous studies. First, the study is a small-scale student project that only accepted students who study an introductory course of psychology for course credit requirement. The sample size is limited to local students who signed up for the study. The number of recruitment reached 46, far less than similar design in the field of bilingual studies. This claim is supported by the fact that many items in a correlational analysis almost reach statistically significant level. Possibly, the statistics are resulted by small sample size.

Second, the sample for the study is consisted of two populations, 33 undergraduates ranged from age 19 to 23 and 13 graduates or postgraduates ranged from age 24 to 57. There may have been large variance from the graduate group of participants. They have had at least one year of working experiences in different occupations, which benefit their abilities in reading
and memory. Occupational influence may result in measurement errors of the tests. On the other hand, there had been reported fatigue from participants before the start of any data collection. Some participants claimed to be exhausted due to their own businesses. For example, most of the older participants were tested at night after a day of work. It is likely that their test performances were affected by psychological and physical exhaustion, causing incongruence between the result and previous findings.

There were no standardized measurement for Chinese reading comprehension and English reading comprehension at the level of difficulty for undergraduate as well as Chinese WM. The study employed these three self-devised measurements. However the tests had shown certain reliability, there is space left for improvement to achieve higher reliability. For instance, the test of Chinese WM adopted the same format as the test of auditory WM in English. There is a likelihood that words in two Chinese characters and numbers imposes influence due to the variability of pronunciation. Linguistically, Cantonese has been recognized to have higher phonological demand and more complex combination of characters with various semantic purposes than English. Homophone is an example considered for word adoption in the test of Chinese WM. The implicit linguistic differences may contribute to the complicated finding by self-devised tests, though satisfactory external validity had been retrieved from well-recognized test of English such as IELTS and public examinations for both languages like Hong Kong Advanced Level Examination and Hong Kong Diploma of Secondary Education.
Second hypothesis predicts a cross-language transfer from L1 WM to L2 reading comprehension, while the third hypothesis proposes L2 WM predicts L1 reading comprehension. As argued before, cross-language transfer in Hong Kong bilinguals is an exploratory replication of local studies in children and studies in other countries targeted at various languages (Keung & Ho, 2009). Given highly different orthographical and phonological structures, one significant and one non-significant findings of cross-language effect are rather informative to explore the reasons why this result contrast exists.

Orthographically, Chinese languages are varied in different regions (Gottardo et al., 2006). Words in Chinese can be produced by combinations of characters. A meaning can sometimes be expressed by one Chinese character, but sometimes it requires more than one character to tell. These innumerous combinations of character are more demanding than words in English, which endorse a holistic specification of letters for a word (Zhou, Marslen-Wilson, Taft, & Shu, 1999). In other words, Chinese characters could be chunked in an overlapping manner that produces various meanings, whereas English letters are allocated to a unique combination to form a meaning (Ramirez, Chen, Geva, & Luo, 2011). By the resources required to process orthographical information in both languages, Chinese characters place more demand on WM. The input of Chinese words stored in WM requires more effort to integrate separated input unit into a complete picture of the passage (Ramirez et al., 2011). In contrast, orthography in English is relatively simple, with a specific string of letters representing a unique meaning.
(Cheung, Chan, & Chong, 2007). There is no orthographic interference from the combination with another word unit. With these advantages, English words require less effort to be stored and manipulated in WM. Hence, more cognitive resources would be spared to semantic analysis and coherence establishment. This may produce a positive prediction from L2 WM to L1 reading comprehension.

Given English words consisted of innumerable strings of letters, the level of demand for WM would raise to certain extent similarly as Chinese language. It is the phonology that counteracts this increase of demand. In English, five vowels and 21 letters were assigned with distinctive phonemes (Liu & Shen, 1977; Wang, Yang, & Cheng, 2009). Hence, every single combination of letters is pronounced in an exclusive manner, which implicitly identifies a word from one and other. Nevertheless, phonology in Cantonese is not the case. It is a language with emphases on nine tones in falling, rising or level contour bind with high, middle or low register in single character (Hashimoto, 1972). Each character is pronounced with an initial onset and a final rime. Most distinctively, one cannot accurately pronounce a Chinese character by reading, just as words in English. Indeed, 80% of Chinese characters are phonograms, each consisted of a semantic radical and a phonetic radical (Tse, 1982). Even if readers can pronounce a character with reference to the phonetic radical, they have to correctly identify one out of nine tonal frequencies before accurate retrieval from WM (So & Dodd, 1995; Zhang et al., 2012). The demandingness for resources in WM would further increase with a word in two Chinese
characters. Phonological differences in two languages may play a part in the contradictory result of the study by imposing varied demandingness of WM resources.

Viewing from reading comprehension, the demandingness of WM indicates the concentration of cognitive resources for processes of informational input. Yet, reading comprehension consists of a series of cognitive activities, such as reorganization of written information, retrieval of previous knowledge from long-term memory for integration and drawing inferences (Rupp et al., 2006). Such tasks may mediate the effect from WM to reading comprehension. The fewer the resources demanded by WM, the more the resources could be allocated to tackle processes of reading comprehension which reveal the strength of effect. Logically, simplicity of orthography and phonology in English suggests a relatively low level of demand in WM and thereby significantly predict Chinese reading comprehension, while Chinese WM is not relate to English reading comprehension.

With such argument, processes of reading comprehension are shared in two languages. In fact, previous studies proposed that the comprehensive tasks are much similar not only in Chinese and English, but also in other languages (Engel & Gathercole, 2012; Leong et al., 2008). What constitutes the commonality is the task structure. Previous studies employ various comprehension tasks like sentences, paragraphs or passage (Chik et al., 2012; Taguchi, 2008). Within these task constrains, the smallest semantic unit is a word. Although there may be variations of grammaticality (Liu & Shen, 1977), orthographical and phonological interference
from word units are minimized by the mediating tasks underlying reading comprehension. The
demand for WM of reading comprehensions in different languages are thereby similar (Cheung
et al., 2007). Thus, current result is argued to be produced by variations of processing demand
within WM instead of processes in reading comprehension.
Chapter 3

3. EXTENDED LITERATURE REVIEW

3.1. Working Memory and Suppressing Ability

Study one denoted language generality of verbal WM exemplified by bilingualism in Chinese and English. It is rare in identifying a relation of L2 WM – L1 reading comprehension without finding a relation of L1 WM – L2 reading comprehension. Thus, study 2 attempted to verify how WM in L1 and L2 with distinctive orthography contribute to irrelevance suppression, one of the processes in reading comprehension. Out of methodological and biased sampling concern, study 2 concentrated on the search for cross-language relation in basic cognitive processing.

When WM received raw verbal input, the processing unit remains as separated words (Otsuka et al., 2003). There have been large differences of processing unit under reading comprehension as the task purpose is changed to processing semantic implications from collections of words, sentences and paragraphs. The minimal unit for comprehension was a clause or phrase that clearly incomparable to word analyzed in WM (Zhiqiang, Donling, Xiangjie, & Hengchao, 2009). It probably disrupts direct connection between WM and reading comprehension. Another line of reasoning refers to the composition of reading comprehension. As indicated by previous literatures, reading comprehension consists of elemental analyses like
integration, inference making and suppression of irrelevant information. These tasks may mediate the relation between WM and reading comprehension since the exercises handle the same level of verbal input as WM (Borella, Carretti, & Pelegrina, 2010). Accordingly, an exploration over the function of WM implemented to the subcomponents of reading comprehension may better illustrate the interactions between WM and reading comprehension in bilinguals.

Suppressing ability under reading comprehension was extracted, for the nature of irrelevance suppression is representative of the functions of WM. Pimperton’s (2010) study tried to address suppressing ability by inducing proactive interference (PI). PI is an impact exerted from previously stored information that impedes the recall of new information (Lin & Luck, 2012; Loosli, Rahm, Unterrainer, Weiller, & Kaller, 2014). The PI paradigm reasons that if one’s WM (including memory span and functioning of articulatory rehearsal) is poor, the performance of PI task is correspondingly poor. In Pimperton’s (2010) study, 28 good comprehenders and poor comprehenders were selected out of 109 children. They were later tested with the PI paradigm in oral recall and word recognition. Results from the experiments suggested a significant relation between suppressing ability and reading comprehension. Therefore, the PI paradigm was adopted in study 2 to operationalize suppressive ability.
3.2. **Within Language Relations of Working Memory and Suppressing Ability**

A fair number of studies were conducted to reveal WM and irrelevance inhibition in reading comprehension (Chiappe, Siegel, & Hasher, 2002; Jerman, Reynolds, & Swanson, 2012; Robert, Borella, Fagot, Lecerf, & De Ribaupierre, 2009; Savage, Cornish, Manly, & Hollis, 2006). While most of them compare WM performance in groups of good or poor comprehender, the studies confirmed poor performance in suppression congruently appeared with deficits observed in WM measures. Clearly, inhibitory mechanism was studied well with WM in western studies. There are, though, a limited number of studies in Chinese context support the relation between WM and suppressing ability. A study consisted of measures including verbal WM, inhibition and updating tasks aimed to find out executive function deficits among children with reading difficulties or mathematic difficulties (Peng, Sha, & Li, 2013). A significant difference has been found in verbal WM, suppression and other reading skills between children with reading difficulties and controlling children. This finding implied a possible relation between verbal WM and suppressing ability in reading domain. Another cross-cultural study comparing Chinese and American preschoolers in a series of executive functioning variables like inhibition, WM and attentional control (Lan, Legare, Ponitz, Li, & Morrison, 2011). Highly significant correlation of WM and suppressing performance was reported. The above evidences proposed a strong within-language relation taking place between the abilities.
3.3. **Cross Language Relations of Working Memory and Suppressing Ability**

In response to the result of study 1, L2 WM was able to transfer the effect to L1 reading comprehension. Logically, WM is also able to transfer its cross language effect to inhibitory functioning as both operate at the basic level of informational process. Although there is no literature addressed this proposal, the deduction is supported by the fact that many cross-language relations have been found among different fundamental reading abilities in L1 and L2 (Leong et al., 2008; Li et al., 2012; Zhong et al., 2002). Then suppressing ability, which is categorized as an executive function of WM in reading domain, is probable to have the same transfer as WM. A research of multilingual children (Engel & Gathercole, 2012) reported executive processes measured by complex span tasks like counting recall and backwards digit recall were related across three languages, pointing to potential cross language transfer between WM and suppressing ability.
Chapter 4

4. STUDY 2

4.1. Research Question and Hypotheses

Study 2 clarifies cross language effect of WM over reading comprehension by specifically focusing on the suppressing performance of PI. (1) Within language relation was expected to be found between WM and suppressing performance in L1 and L2. Cross language transfers were hypothesized in (1) L1 WM and L2 PI performance, and (2) L2 WM and L1 PI performance.
4.2. Methodology

4.2.1. Participants

The same group of participants in study 1 were accepted to conduct PI tasks, including 46 local undergraduates and postgraduates (17 males, 29 females). They were qualified as a bilingual in the same criteria stated before.

4.2.2. Material and Procedures

Participants were asked to perform three PI tasks. Of which two are verbal tasks in L1 and L2. In order to control domain generality of central executive, a nonverbal PI task was given to participants for statistical control.

**Verbal proactive interference – English.** Current PI paradigm from a study (Pimperton & Nation, 2010) was modified. The PI task was designed in E-prime program (Schneider, Eschman, & Zuccolotto, 2001) to test one’s ability to suppress irrelevant information from WM. Participants were first presented with instructions on a computer screen. They were asked to identify if a target word had been presented in the latest block of words. After the instructions, there were five practice trials for procedural familiarization. The task is comprised of 24 trials in three conditions commenced in random order. The word stimuli were shown in black at the center of the screen under a white background with the font in Times New Roman. The font size of each stimulus was 16.
There were eight single block trials to keep participants concentrating on the first
block in the design. Starting with a fixation cross presented on the center of the screen for 1000
ms, participants were sequentially shown with four English words per 1000 ms. Two sets of five
digits then sequentially appeared per 1000 ms and were required to shadow. Questions were
asked with a bolded categorical cue (i.e. jewelry) and target word (i.e. ring). [e.g. Was the
jewelry you saw a ring?]

The 16 double block trials adopted the first sequence except for a cross presented for
1000 ms after the first block of words. Another block of four words was given progressively
following by two sets of five digits and a question. The cross suggests that participants should
forget what they saw before and retain the coming four words to answer the question.
Participants were instructed to press labeled keys for “yes” or “no”. Next trial proceeds only if a
response was made.

16 double block trials were divided into eight non-interference trials and eight
interference trials. Interference trial is different from non-interference trial in presenting two
words from the same category in respective blocks. In this sense, the first word serves as a foil
word while the second was a target. Questions in this condition were asked with a foil word with
the categorical cue, to which correct answers are negative to suggest no PI occurred.
Nevertheless, questions in non-interference trials were asked for words identification in second
block without semantic interference. Hence, PI can be contrasted between non-interference trial
and interference trial with a controlling design of the former, but not the latter. Target words do not appear in half of the single block and non-interference trials. Correct answers to these trials are half positive and half negative.

From the previous study, the words were selected from Children’s Printed Word Database based on the following criteria (Masterson, Dixon, & Stuart, 2002). Firstly, target, foil and filler words have the same frequency of usage per million words. Secondly, all the words are limited to two syllables to ensure no confound from word length. Each block is consisted of three fillers and one target or foil. To eliminate primacy and recency effect, all the targets and foils were placed in either second or third presentation in counterbalanced fashion. Performances are evaluated by accuracy and reaction time.

**Verbal proactive interference – Chinese.** This is a Chinese version of PI task constructed in the same way as the English PI task in the study (Schneider et al., 2001). The task contains the same number of trials, conditions and presenting method and duration as the English version of PI task. The only difference is the text material. Each word block was aggregated of four Chinese words that each consisted of two Chinese characters. Questions were also asked in Chinese with a categorical cue (i.e. 一種刊物; a type of reading) and a target word (i.e. 雜誌; magazine). [e.g. 您剛看見的一種刊物是雜誌嗎?; Was the type of reading you saw magazine?]
The stimuli were chosen from the dictionary (Chinese National Language Committee, 1998), in which words are commonly known in daily life. The same semantic groups in the English PI task were selected. Yet, the stimuli were not the same as those in English PI task to avoid memory transfer across languages. Randomization on the semantic groups to three conditions was also complemented.

**Non-verbal interference.** Similarly, the task is designed in E-prime (Schneider et al., 2001) and consisted of three conditions as single block trials, non-interference and interference trials in verbal PI task. 30 trials were evenly distributed to each condition: ten for single block, ten for non-interference and ten for interference condition. The test takes a form of facial recognition to avoid memory intrusion from any verbal information.

The single block trials were added to keep participants focusing on the first block of stimuli. Presenting with a fixation cross on the screen for 1000 ms, three faces were progressively presented under a white background per 1000 ms. A question mark then appears for 1000 ms followed by a question face. The question mark suggests the following face as a question to whether it had appeared in the block or not. Response is required before continuing. Participants pressed keyboard labels for “yes” or “no”. 20 double block trials have the same structure for the first block followed by a cross, which indicates previous learning should be forgotten. The second block then appears with other three faces, a question mark and a target
face. The question mark indicates a question over the appearance of the target face in the second block or not.

In non-interference trials, the target face only appears in the second block as a control condition as opposed to interference trials. In contrast, target face only appears in the first block of interference trials, which is supposed to be ignored in consideration of answer. PI is prompted when participants answer positively in interference trials. For single block and non-interference trials, half of the target stimuli were not included in the trials suggesting answers to these trials are half positive and half negative.

Face-Place Face Database provides facial stimuli in neutrality needed in this task. (Tarr, 2007). All faces are photographically shown in colored format. Randomization over races and presenting sequence were implemented to produce each block of three faces. Each block must consist of one Asian, one African and one Caucasian faces. Gender of the faces was also randomly arranged in blocks. Primacy and recency effect were prevented by placing target face in the middle of a block.
4.3. Results

PI tasks measuring one’s ability in suppressing irrelevant information involve central executive in the model of working memory. Accuracy and reaction time was captured to indicate the ability. There is moderate correlation between L1 WM and L2 PI reaction time in single block trials, $r(44) = -.36, p < .05$, non-interference trials, $r(44) = -.33, p < .05$, and interference trials, $r(44) = -.39, p < .01$.

Considering confounding effect from phonological STM, performance of single block trials was excluded. The mean of accuracy and reaction time of double block trials in different languages were calculated. The mean accuracy in L1 PI task ($M = 0.9, SD = 0.14$) is similar to L2 PI task ($M = 0.89, SD = 0.12$). L1 PI task takes more time ($M = 1556.05, SD = 592.68$) than L2 PI task ($M = 1288.09, SD = 463.64$). (see Table 4)

Table 4
Descriptive statistics of performance of Double Block Trials in L1 and L2 Task of Proactive Interference

<table>
<thead>
<tr>
<th>Variables</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 Accuracy</td>
<td>0.9</td>
<td>0.14</td>
</tr>
<tr>
<td>L1 Reaction Time (ms)</td>
<td>1556.05</td>
<td>592.68</td>
</tr>
<tr>
<td>L2 Accuracy</td>
<td>0.89</td>
<td>0.12</td>
</tr>
<tr>
<td>L2 Reaction Time (ms)</td>
<td>1288.09</td>
<td>463.64</td>
</tr>
</tbody>
</table>
Employing the mean PI accuracy and reaction time, a correlational analysis (see Table 5) revealed that there was positive relation between L1 WM and L1 mean PI accuracy in double block trials, $r(43) = .36$, $p < .05$. Having controlled the age, regression analysis showed that L1 WM significantly predicted L1 mean PI accuracy of double block trials, $\beta = .28$, $t(44) = 2.08$, $p < .05$, and explained variance, $R^2 = .28$, $F(2, 42) = 8.27$, $p < .05$. (see Table 6)
Table 5  
Correlations of L1/L2 Working Memory and Performance of L1 Proactive Interference Task

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
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<tr>
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<tr>
<td>6. Reaction Time of Non-interference Trials</td>
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<td>.03</td>
<td>-.27</td>
<td>-.03</td>
<td>.84**</td>
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<td>7. Reaction Time of Interference Trials</td>
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<td>.84**</td>
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<td>8. Mean Accuracy of Double Block Trials</td>
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<td>.20</td>
<td>.36*</td>
<td>-.14</td>
<td>-.24</td>
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<td>-.19</td>
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<td>.94**</td>
<td>.97**</td>
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<td>10. Mean IES of Interference Trials</td>
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<td>.07</td>
<td>-.19</td>
<td>.36*</td>
<td>.26</td>
<td>.33*</td>
<td>.46**</td>
<td>-.62**</td>
<td>.42**</td>
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<td>11. Mean IES of Double Block Trials</td>
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<td>.00</td>
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<td>.08</td>
<td>.73**</td>
<td>.82**</td>
<td>.83**</td>
<td>-.64**</td>
<td>.85**</td>
<td>.69**</td>
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</tbody>
</table>

*Note.* *p < .05, **p < .01
Table 6

*Regression statistics of L1 Working Memory Predicting L1 Performance of Proactive Interference Task with Age Controlled*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model $R^2$</th>
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<th>$SE B$</th>
<th>$\beta$</th>
<th>$t$</th>
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<td>Mean Accuracy of Double Block Trials</td>
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<td>.01</td>
<td>.01</td>
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<td>2.08*</td>
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<td>Mean IES of Double Block Trials</td>
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<td>-82.35</td>
<td>34.8</td>
<td>-.33</td>
<td>-2.37*</td>
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</table>

*Note. *p < .05, **p < .01*
There was a negative relation between L1 WM and L2 mean PI reaction time in double block trials (see Table 7), $r(44) = -.40, p < .01$. A regression analysis suggests (see Table 8), L1 WM predicted L2 mean reaction time in double block trials, $\beta = -.40, t(45) = 2.88, p < .01$, and explained a proportion of variance, $R^2 = .16, F(1, 44) = 8.27, p < .01$. 
Table 7

Correlations of L1/L2 Working Memory and Performance of L2 Proactive Interference Task

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<thead>
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<th>Variables</th>
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<td>4. L2 Working Memory</td>
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<tr>
<td>5. Reaction Time of Single Block Trials</td>
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<td>6. Reaction Time of Non-interference Trials</td>
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<td>-.27</td>
<td>.84**</td>
<td>.84**</td>
<td>.85**</td>
<td>-.38**</td>
<td>.92**</td>
<td>.86**</td>
<td></td>
</tr>
</tbody>
</table>

Note. *p < .05, **p < .01
### Table 8

Regression statistics of L1 Working Memory Predicting L2 Performance of Proactive Interference Task

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Reaction Time of Double Block Trials</td>
<td>-53.09</td>
<td>18.46</td>
<td>-.40</td>
<td>-2.88**</td>
</tr>
<tr>
<td>Mean IES of Interference Trials</td>
<td>-116.91</td>
<td>32.91</td>
<td>-.47</td>
<td>-3.55**</td>
</tr>
<tr>
<td>Mean IES of Double Block Trials</td>
<td>-68.60</td>
<td>21.29</td>
<td>-.44</td>
<td>-3.22**</td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .01*
The above result addresses few for overall performance of PI task. PI paradigm possibly introduced speed-accuracy tradeoff to the performance. Some studies proposed that statistical bias may occur considering only reaction time or accuracy. Accordingly, Inverse Efficiency Score (IES) was adopted to summarize the PI performance integrating accuracy and reaction time. Dividing mean reaction time by mean accuracy results in IES. Subsequently, IESs of interference trials in L1 and L2 were taken into a correlational analysis and found that there is a significant relation between L1 WM and L2 IES of interference trials, \( r(43) = -.47, p < .01 \). Regression confirmed that L1 WM is a strong predictor of L2 IES of interference trials (see Table 8), \( \beta = -.47, t(45) = -3.55, p < .01 \) and predicts variance, \( R^2 = .22, F(1, 44) = 12.62, p < .01 \).

Positive relation was also found between L2 WM and L1 IES for interference trials, \( r(43) = .36, p < .05 \). Significant regression indicated that L2 WM predicts L1 IES in interference trials (see Table 9), \( \beta = .37, t(44) = 2.75, p < .01 \). It explains a proportion of variance, \( R^2 = .26, F(2, 44) = 7.26, p < .01 \) with age controlled.
Table 9

*Regression statistics of L2 Working Memory Predicting L1 Mean IES of Interference Trials in Proactive Interference Task*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model $R^2$</th>
<th>$B$</th>
<th>SE $B$</th>
<th>$\beta$</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>158.96</td>
<td>64.639</td>
<td>.35</td>
<td>2.46*</td>
</tr>
<tr>
<td>Step 2</td>
<td>.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>160.06</td>
<td>60.21</td>
<td>.35</td>
<td>2.66*</td>
</tr>
<tr>
<td>L2 Working Memory</td>
<td></td>
<td>339.46</td>
<td>123.49</td>
<td>.37</td>
<td>2.75**</td>
</tr>
</tbody>
</table>

Note. *p < .05, **p < .01

Regression analysis further suggested predictability of L1 WM to mean IES of double block trials in L1 and L2 (see Table 6 & 8). Among L1 WM and L1 mean IES of double block trials, moderate coefficients after control for age indicate relatively low variance explained, $\beta = -.33, t(44) = -2.37, p < .05, R^2 = .23, F(2, 42) = 6.17, p < .05$. A strong predictability was revealed from L1 WM to L2 mean IES in double block trials, $\beta = -.44, t(45) = -3.22, p < .01, R^2 = .19, F(1, 44) = 10.39, p < .01$. 

Note: It seems there's a typo or an error in the provided text. The regression analysis results are presented in a table, but the details of the results and analysis are not fully transcribed here. The context suggests a discussion of predictability and variance explained in the context of working memory and interference trials. Further details and calculations related to the coefficients, $t$-values, and $p$-values are not fully shown here.
4.4. Discussion

At the basic level of informational processing, WM was generally related to PI indicators showing respective relations to WM. Predictability of WM over PI accuracy and reaction time were shown by regression analysis. More importantly, language transfers were discovered among WM and performance in PI task indicating the nature of suppressing ability as shared across L1 and L2.

A positive within-language relation was found between L1 WM and L1 mean PI accuracy in double block trials. This finding is common in literatures and enough to tell there is a within language effect for L1 (Otsuka et al., 2003; Peng et al., 2013). Indeed, the study is unable to find any connection from L1 WM to L1 mean PI reaction time. It is possible that reaction time reflects much more than accuracy in individual response, which leads to a relative large variance in statistics. For instance, the variance may come from visual ability and speed for cognitive processing.

For the lack of within language relation of L2, the result is reasonable considering the degree of familiarity and expertise in L1 was more proficient than L2. Familiarity of language could play an important role in the reading analysis with WM and suppressing tasks (Shi, & Sánchez, 2011). Practices and knowledge of language produce a stable mental representation of language in use. With the pre-established representation in mind, linguistic
tasks could be more efficiently executed. Further discussion in IES of PI double block trials offers another piece of evidence that language familiarity possibly contributes to current findings of within language relation. The role of language familiarity in bilingual tasks provides potential explanation to the findings of within language relation in L1 WM and suppressing performance, and missing relation yet well-supported within language effect in L2 WM and suppressing performance.

Second and third hypotheses were formulated to examine a specific mechanism underlying reading comprehension – suppressing ability of irrelevant information. The second hypothesis indicated that L1 WM predicts reaction time in task of PI in L2, whereas the third hypothesis proposed that L2 WM predicts reaction time to task of PI in L1. Surprisingly, the bilingual relation between WM and performance in PI task is a total opposite to the bilingual relation between WM and reading comprehension. Proposed explanation is made referring to capacity and efficiency of WM differed across languages.

The second hypothesis was mainly supported with a negative correlation between L1 WM and mean reaction time in L2 double block trials, indicating a connection among PI and resources coordination between two subcomponents of phonological loop in the model of working memory: phonological store and articulatory rehearsal. Since L1 has advantages in earlier development and common practice, bilingual’s WM is likely to be shaped to deal with the heavy demand due from linguistic characteristics in L1 (Lee, Kim, & Zoh, 1996). Thus,
resulting relatively large WM span and manipulative efficiency are well-adjusted to solve PI by suppressing irrelevant information (Jerman et al., 2012; Loosli et al., 2014). In other words, the better the performance of WM is, the more the influence from the language exerts on the suppressing performance. Bilinguals have been argued to have efficient executive functions such as suppression of irrelevance, planning efficiency and problem solving. Current analogy suggests that a significant predictability from L1 WM to L2 suppressing performance provides a possible cause of executive efficiency of bilingual in verbal domain (Robert et al., 2009).

Performance of PI analyzed in IES supports the inference of directional effect from L1 WM to L2 suppressing performance in both interference trials and double block trials. It is evident that L1 WM, which has larger capacity and efficiency, predicts suppressive ability in general. However, interpretation of IES should be cautious (Bruyer & Brysbaert, 2011; Donkin, Brown, & Heathcote, 2011). IES assumes that accuracy and response rates are linearly related, from which it resolves the speed and accuracy tradeoff elicited by variables of accuracy and reaction time in behavioral measures (Bruyer & Brysbaert, 2011).

The third hypothesis is rejected by the non-significant relation between L2 WM and reaction time to task of PI in L1. English in Hong Kong bilinguals is defined as a second language. In comparison with Chinese, English is relatively less in use for conversation and
written communication despite academic emphasis since elementary education. Accordingly, capacity and efficiency in employing WM are underdeveloped, without distinctive relation found between WM and suppressive performance. Although there is a relationship found between L2 WM and L1 IES of PI task in interference trials, the result is reserved to be evident in supporting the third hypothesis out of mathematical challenges of IES from previous research (Bruyer & Brysbaert, 2011).
Chapter 5

5. GENERAL DISCUSSION AND CONCLUSION

5.1. Executive Processes for Working Memory and Comprehension in Two Languages

Referring to the discussions, there are two directions for WM exerting influence.

First, the effect of WM transmits in a hierarchal manner to reading comprehension, through mediating processes for comprehension. Despite many successful demonstrations by previous research, this type of effect transition is not directly examined. In addition to the complication of the underlying tasks in reading comprehension, models for reading comprehension are varied. Demandingness for WM due to linguistic characteristics is thereby argued to be a distinction between L1 and L2, so does the effect transition to reading comprehension.

The second effect transition of WM is horizontally examined in study 2, in which both WM and PI task adopt the same level of linguistic unit for further processes. By addressing the capacity and efficiency of WM in L1 and L2, this has been argued to be related to overall suppressive ability across languages which commonly known to be included in reading comprehension. The effect of WM to suppressing ability and reading comprehension is partially disclosed by the study.
5.2. Conclusion

The study attempted to identify the interactions between WM and reading comprehension, and suppressing ability in L1 and L2. Significances were generated by current findings. First, L2 WM and L1 reading comprehension was found in adult bilinguals in Hong Kong. It extends cross language influence from adolescence to adulthood and enriches bilingual literatures in Chinese. Second, the relations of WM and suppressing ability support implicit influence from WM and reading comprehension. As one of the underlying process of reading comprehension, irrelevance suppression reveals a nature shared across L1 and L2. A potential mediating route from WM to reading comprehension was supported by the results providing a foundation for in-depth studies.

5.3. Limitations and Future Research

Nonetheless, there are shortcomings in the study. First, the study targeted adults as the sample to investigate the relation among WM, reading comprehension and informational suppression. Due to small range of age among participants, no cross-sectional comparison of phonological WM, reading comprehension and other cognitive abilities could be drawn in adulthood. Second, the measurements of reading comprehension in L1 and L2 are designed on our own. Relatively low reliability was captured in measures of English reading comprehension, which leaves reservations for interpretation of data. Third, the tests
were administered in two separated one-hour sessions. Some participants requested to conduct the sessions successively. Fatigue effect may degrade the tests performance. The effect may also display in other participants reported exhaustion as well. Fourth, IES was utilized to reflect the general performance in PI tasks. Cautions should be taken to the scores as progressively more research indicated that there may be more complex mathematical issues to be solved in managing data of accuracy and reaction time. Second, relation was not found between performance in PI tasks and reading comprehension. This lack of relation block the way for further delineation of interaction among WM, suppressing ability and reading comprehension.

Further studies are encouraged to consider the relations of verbally analytical processes included in reading comprehension and WM. Theoretical discussion of structures and functions of WM in Hong Kong bilinguals enriches the literatures of studies in distinctive linguistic characteristics to cognitive abilities. General executive functioning in not only languages but also other domains like mathematics and perceptual learning could also be studied with bilinguals. Further research emphasis may be placed on the mechanisms of cross-language WM and reading comprehension.


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