Effect of Physical Cleanliness and Cognitive Cleanliness on Moral Judgment

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Abstract

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

Introduction

General Introduction

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

The Model of Working Memory was initially contended by Baddeley and Hitch (1974), as an attempt to exemplify conceptual cognition when coping with informational input. The model consists of three main components. Central executive was proposed as the organiser 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. Phonological loop was described to deal with the linguistic input from different sensory modalities, and visual-spatial sketchpad deals with pictorial patterns and spatial information. In accordance with the model, reading and listening ability were dependent on phonological loop, which attracted interest in investigation of the relationship 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). Cultural and historical factors suggest that educational emphasis has resulted in bilingual development among people in Hong Kong (Gottardo, Chiappe, Yan, Siegel, & Gu, 2006; Zhong, McBride-Chang, & Ho, 2002). The study included people in Hong Kong in order to determine the 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 processes for the acquisition of meanings from sentences, paragraphs and a whole page. 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 errors of intrusion, as well as other processes making use of WM (Daneman & Carpenter, 1980).

General Relationship between WM and Reading Comprehension

In western literature, there has been strong evidence indicating WM's predictive ability in reading comprehension. A large number of studies documented the relationship between WM and reading comprehension, for countries located in Asia and Europe (Cain, Oakhill, & Bryant, 2004; Kondo, Morishita, Ashida, Otsuka & Osaka, 2003; Lee, Kim, & Zoh, 1996; Morishita, Kondo, & Osaka, 2003; Naumann, Richter, Goff, Pratt, & Ong, 2005; Seigneuric & Ehrlich, 2005).

Given the rich combination of studies found in a meta-analysis (Daneman & Merikle, 1996), a confident claim can be made in support of the predictive power of WM over language comprehension.

L1 Working Memory and L1 Reading Comprehension

Considering Chinese as L1 among individuals in Hong Kong, studies found that verbal WM is related to levels of text comprehension. A study investigated 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 together with performance in reading comprehension tasks in four passages. Other reading-related variables such as pseudo-word reading and rapid automatised naming (RAN) were collected from 518 children in Hong Kong at the level of primary education. The results suggested that a large proportion of variance in text comprehensive performance was explained by Chinese verbal WM, congruent with previous research in the western world.

Another study revised the model of reading comprehension with 248 Chinese in 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 were able to predict reading comprehension while word reading was statistically controlled. What is worth noting is that Chinese verbal WM has contributed to reading comprehension, which is one of the reasons the current study further explores the relationship between verbal WM and reading comprehension in a Chinese context.

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

L2 Working Memory and L2 Reading Comprehension

A strong connection was found between English verbal WM and English reading comprehension in the L2 domain (Lipka & Siegel, 2010; Low & Siegel, 2005). A study in Turkey with 43 participants aimed to determine the relationship between 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 was conducted in a Japanese study under a L1 background with more varied orthography and phonology compared to English. Japanese participants were recruited for a performance examination of the Reading Span Task (RST) (Osaka & Osaka, 1992). A correlational analysis was conducted with scores of TOEFL reading categories and the performance of a cloze test with 350 words. Significance was discovered in the relationship between RST and TOEFL reading scores, supporting the transfer from L2 WM to L2 reading performance despite different language characteristics.

Working Memory and Reading Comprehension – Cross Language Effect

Cross-language transfer is debatable. Research has found that transfer occurs on condition that L1 and L2 linguistic characteristics are similar to each other. It is possible that verbal WM is shaped and adjusted according to language demand. Indeed, studies evaluating 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 such as the Pragmatic Listening Test and the Lexical Access Test, which assessed the ability to comprehend underlying intention and how quickly a semantic extraction could be made (Taguchi, 2008).

There are empirical discoveries that argue against the assertion. For instance, a study measuring reading skills including word reading, RAN, phonological and orthographical identification suggested multiple cross language transfers between skills (Keung & Ho, 2009). Findings such as interrelations 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 a cross language effect in the reading domain even in two phonologically and orthographically varied languages. Furthermore, the result of a longitudinal study monitored the reading development of 141 children in Hong Kong for two years (Li, McBride-Chang, Wong, & Shu, 2012) and showed that spelling and reading comprehension were correlated across two languages. The above evidence favours the cross language effect at lower level reading tasks involving cognitive skills.

Adult Bilingual Sampling

Previous studies mostly selected children as the targets of research into reading skills and relevant variables (Goff et al., 2005; Zhong et al., 2002). One of the drawbacks in collecting data from children is that their test performances are developmentally limited. Both cognitive abilities and reading experiences are fairly constrained. It is therefore unlikely to find sufficient information and to be able to summarise reading ability in other life stages (Hu, 2008). On the other hand, some studies adopted adults and college students with unstable L2 representation backgrounds, such as those who participated in accelerated English courses. The advantages or deficits of cognitive ability and reading skills cannot be fully explained by bilingualism (Li, 2008). Even though the participants had mastered English as certified by international qualifications, the degree of attribution to the established representation of L1 and concurrent cognitive ability, and the way L2 contributes to language development are questionable. The current study addresses the above sampling issues by recruiting young adults in Hong Kong and explores influences from bilingualism to comprehensive analysis during reading.

Research Question and Hypotheses

The present study explored interactions between WM and reading comprehension in bilinguals. In accordance with the literature review, (1) A within-language relationship was expected between L1 WM and L1 reading comprehension, and between L2 WM and L2 reading comprehension. relationships were expected to be found across languages in the form of (2) L1 WM – L2 reading comprehension, and (3) L2 WM – L1 reading comprehension.

Methodology

Participants

The sample was recruited from an introductory psychology class, and fulfilled a course credit requirement, and included 46 local undergraduates and postgraduates (17 males, 29 females) aged 19 – 47 years (mean age: 24.11). The criteria for being 'bilingual' was the use of L1 in any form at home and in most daily communication, and participants must have been Cantonese-speaking individuals who learned English as a second language (ESL).

Materials and Procedures

Prior to any tests, a consent form was given to participants . Demographic information was collected in the form providing space for participants to fill out their test answers.All the participants were evaluated with a series of tests as the following indicates, particularly for tests 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 was Cantonese, except for tasks in English versions. Of the above tasks, reading comprehension and verbal WM were tested in their respective languages.

Raven's standard progressive matrices. Raven's progressive matrices were used to measure non-verbal intelligence (Raven, 1938), which needs to be controlled as it is commonly related to reading tasks. Five sets of matrices were designed in a standard version. Each set consisted of 12 multiple choice questions that required participants to answer from eight provided choices on the basis of logical inference from 2x2 and 3x3 matrices. The test is progressively difficult from set A to set E, and is suitable to be administered to children at five years of age and the elderly. In the current study, only set D and set E were adopted in accordance with the level of difficulty, as the sample consisted of adults. Each correct answer scored one mark. The total score was 24, with Cronbach's α at .77.

English reading comprehension. Three passages of approximately 850 words each on average were chosen from the website http://www.howstuffworks.com. Issues of science, economics and culture were discussed respectively in each passage. Participants were given 20 minutes to finish 15 MC questions and to write their answers on a test form provided. No writing on the testing material was allowed, to control possible confounds from reading skills. The highest mark for this task was 15, Cronbach's α was .49.

Chinese reading comprehension. The test consisted of three passages from old newspapers [men mei po] in 2000 and 2001. There were around 1000 characters per article and 15 multiple choice questions devised based on the passages discussing

social problems in Hong Kong The comprehension level for each passage was tested with five questions. Participants were required to select from choices offered and write them on paper within 20 minutes. No writing on the testing material was allowed to control possible confounds from reading skills. Out of the same consideration in the Chinese version, no writing on the testing material was allowed. The highest mark for this task is 15, Cronbach's α 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 a maximum of seven compounds in a set. Scores were given for accurate pronunciation and congruity between reporting order and recording order. An order mark was given when two non-words were reported in the same order as the recording. No score for ordering was given to only one non-word, however, one mark would be deducted if there was any non-word pronounced more than in the concurrent recording. The total marks for the test were 108, with Cronbach's α at .63.

Chinese comprehensive test of phonological processing (CTOPP). The Chinese version of CTOPP takes the same format as the English version (Wagner et al., 1999). The test asked participants to accurately report Chinese characters in the same tonal frequency according to the presenting order. There were eight blocks ranging from five to twelve characters. The blocks were presented and reported in an increasing manner. Marks were given to reading accuracy and reporting correctness, for which the total marks were 128, with Cronbach's α at .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 requires compliance with the original sequence. The materials and arrangements were pre-set 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 consisted of three trials and there were 18 trials in total. The test starts with a block of three items and continues in ascending order. The task was terminated when participants gained no marks from a group of six trials. Scores were given to each correct order of word and numbers in the trials. The maximum mark for a trial was two and the total mark for all trials was 36. Cronbach's α was .61.

Auditory working memory – Cantonese. The exact procedure was adopted from the same format in the 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 in different combinations. Similarly, this test starts with a block of the fewest items and proceeds to blocks with more and more items. . Two points was granted in a trial on conditions of a correct order in words and numbers. Cronbach's α was .69.

Chinese words were selected according to simplicity and the avoidance of homophonic pronunciation with numbers. Each word consisted of two Chinese characters pronounced with two phonemes, and single digit numbers in Chinese were pronounced with one phoneme. The measures prevented possible effects on scoring accuracy from phonemic priming and encoding ambiguity.

Spatial relationships. A series of visual patterns were given to participants to assess visual-spatial ability (Woodcock et al., 2001). A composite picture consisting of two or three pieces was presented. The task required participants to identify the fragments that build the composite. The task was terminated when the score did not achieve the standard of a section. There were 81 trials in total and two cut-offs were distributed at 10 and 56 points. A correct item was scored at one point. Cronbach's α was .73.

Results

The means and standard deviations of demographics and reading variables are listed in Table 1. Correlational analysis was conducted to detect the relationships between 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

Variables	M	SD
Demographics		
Age	24.11	6.43
Years of Studying Chinese	20.82	5.73
Years of Studying English	20.00	6.12
Reading Variables		
Raven's Progressive Matrices	19.91	3.03
L1 Reading Comprehension	6.09	1.87
L1 Working Memory	23.39	3.47
L1 CTOPP	75.33	12.55
L2 Reading Comprehension	10.5	2.00
L2 Working Memory	17.7	3.20
L2 CTOPP	93.67	10.52

No within-language effect was found between WM and reading comprehension in either L1 nor L2 (see Table 2). A relationship between L1 WM and reading comprehension was not significant, $r(44) = .11$, $p > .05$. The same relationship in L2 was not significant, $r(44) = -.17$, $p > .05$.

Table 2

Correlations of Demographics and Reading Variables

Variables	1	2	3	4	5	6	7	8	9	10
1. Age	1									
2. Years of Studying Chinese	.83**	1								
3. Years of Studying English	.88**	.92**	1							
4. Raven's Progressive Matrices	.09	.01	.04	1						
5. L1 Reading Comprehension	-.23	-.17	-.20	.35*	1					
6. L1 Working Memory	-.20	-.06	-.08	.02	.11	1				
7. L1 Short-term Memory	-.11	-.01	-.11	.01	.00	.37*	1			
8. L2 Reading Comprehension	.15	.25	.23	.26	-.18	.03	.02	1		
9. L2 Working Memory	-.01	-.15	-.03	-.06	.33*	.26	.29*	-.17	1	
10. L2 Short-term Memory	-.43**	-.37*	-.33*	.10	.08	.36*	.33*	-.03	.26	1

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

No cross language relationship was found between L1 WM and L2 reading comprehension, $r(44) = .03$, $p > .05$. Surprisingly, L2 WM was 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 for 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

Variable	Model R^2	*B*	*SE B*	β	*t*
Step 1	.12				
Raven		.16	.07	.35	2.44*
Step 2	.25				
Raven		.17	.06	.37	2.77**
L2 Working Memory		.15	.06	.36	2.67*

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

Discussion

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

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

Secondly, the sample for the study 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 among the graduate group of participants. They have had at least one year of working experience in different occupations, which benefits their abilities in reading and memory. Occupational influence may result in the measurement errors of the tests. On the other hand, fatigue was reported 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 standardised measurements for Chinese reading comprehension and English reading comprehension at the level of difficulty for undergraduates or Chinese WM. The study employed these three self-devised measurements, however although the tests had shown certain reliability, there is space left for improvement in achieving higher reliability. For instance, the test for Chinese WM adopted the same format as the test for auditory WM in English. There is a likelihood that words in two Chinese characters and numbers have an effect due to the variability of pronunciation. Linguistically, Cantonese has been recognised as having a higher phonological demand and a more complex combination of characters with various semantic purposes than English. Homophones are an example considered for word adoption in the test for Chinese WM. The implicit linguistic differences may contribute to the complicated findings from self-devised tests, although satisfactory external validity has been achieved from well-recognised tests of English such as IELTS, and public examinations for both languages, such as the Hong Kong Advanced Level Examination and Hong Kong Diploma of Secondary Education.

The second hypothesis predicts a cross-language transfer from L1 WM to L2 reading comprehension, and the third hypothesis proposes that 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 of various languages (Keung & Ho, 2009). Given the very different orthographical and phonological structures, there are informative findings, both significant and non-significant, that are informative about the reasons for the contrasting results.

Orthographically, Chinese languages vary across 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, and sometimes requires more than one character. The innumerous combination of character are more demanding than words in English, which use a holistic specification of letters to make 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 unique combinations to form meaning (Ramirez, Chen, Geva, & Luo, 2011). Through 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 separate input units 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 when combined with another word unit. With these advantages, English words require less effort to store and manipulate in WM, and thus more cognitive resources can be spared for semantic analysis and establishing coherence. This may produce a positive prediction from L2 WM about L1 reading comprehension.

Given that English words consisted of innumerous 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 increased demand. In English, five vowels and 21 letters were designed with distinctive phonemes (Liu & Shen, 1977; Wang, Yang, & Cheng, 2009). This is not the case for phonology in Cantonese It is a language where single characters emphasise one of nine tones in falling, rising or level contours, bound with high, middle or low registers (Hashimoto, 1972). Each character is pronounced with an initial onset and a final rime. Most distinctively, one cannot accurately pronounce a Chinese character simply by reading it, as words in English can be pronounced. 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 high demand for resources in WM would be further increased with a word in two Chinese characters. Phonological differences in the two languages may play a part in the contradictory results of the study by imposing varied demand for WM resources.

From the perspective of reading comprehension, the demand of WM indicates the concentration of cognitive resources for processes of informational input. Reading comprehension consists of a series of cognitive activities, however, such as the reorganisation of written information, and the retrieval of previous knowledge from long-term memory for integration and drawing inferences (Rupp et al., 2006). Such tasks may mediate the effect of WM on 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, the simplicity of orthography and phonology in English suggests a relatively low level of demand on WM and thereby significantly predicts Chinese reading comprehension, whereas Chinese WM is not related to English reading comprehension.

According to such an argument, the processes of reading comprehension are shared in the two languages. In fact, previous studies have proposed that comprehension tasks are 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 employed various tasks of comprehension such as sentences, paragraphs or passages (Chik et al., 2012; Taguchi, 2008). Within these task constraints, the smallest semantic unit is a word. Although there may be variations in grammar (Liu & Shen, 1977), orthographic and phonologic interference from word units is minimised through the mediating tasks underlying reading comprehension. The demands on WM in reading comprehension in different languages are thereby similar (Cheung et al., 2007). It is thus argued that the current result is produced by variations in processing demands within WM instead of in the processes of reading comprehension.

Study Two

Extended Literature Review

Working Memory and Suppressing Ability

Study One demonstrated the language generality of verbal WM, as exemplified by bilingualism in Chinese and English. It is rare to identify a relationship between L2 WM – L1 reading comprehension without finding a relationship between L1 WM – L2 reading comprehension. Study Two thus attempted to verify the way that WM in L1 and L2 with distinctive orthography contributes to irrelevance suppression, one of the processes in reading comprehension. Due to concerns about methodological and biased sampling, Study Two concentrated on the search for a cross-language relationship in basic cognitive processing.

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

Suppressing ability under reading comprehension was extracted, because the nature of irrelevance suppression is representative of the functions of WM. Pimperton's (2010) study tried to address suppression ability by inducing proactive interference (PI). PI is an impact taken 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 WM (including memory span and functioning of articulatory rehearsal) is poor, then performance of PI tasks is correspondingly poor. In Pimperton's (2010) study, 28 children with good and poor comprehension skills were selected out of 109. They were later tested in the PI paradigm in oral recall and word recognition. Results from the experiments suggested a significant relationship between suppressing ability and reading comprehension. The PI paradigm was therefore adopted in Study Two to operationalise suppressive ability.

Within Language Relationships between Working Memory and Suppressing Ability

A number of studies have been 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 comprehenders, the studies confirmed poor performance in suppression congruently with deficits observed in WM measures. Clearly, the inhibitory mechanism was studied well with WM in western studies. There are, however, a limited number of studies in the Chinese context supporting the relationship between WM and suppressing ability. A study consisting of measures including verbal WM, inhibition and updating tasks aimed to determine executive function deficits among children with reading difficulties or mathematic difficulties (Peng, Sha, & Li, 2013). A significant difference was found in verbal WM, suppression and other reading skills between children with reading difficulties and a group of control children. This finding implied a possible relationship between verbal WM and suppression ability in the reading domain. Another cross-cultural study compared Chinese and American preschoolers in a series of executive functioning variables such as inhibition, WM and attentional control (Lan, Legare, Ponitz, Li, &

Morrison, 2011). A highly significant correlation between WM and suppressing performance was reported. The above evidence suggests a strong within-language relationship between the abilities.

Cross Language Relationships of Working Memory and Suppressing Ability

In response to the results of Study One, L2 WM was seen to transfer the predicting 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 the informational process. Although there is no literature addressing this proposal, the deduction is supported by the fact that many cross-language relationships have been found among different fundamental reading abilities in L1 and L2 (Leong et al., 2008; Li et al., 2012; Zhong et al., 2002). Suppressing ability, which is categorised as an executive function of WM in the reading domain, probably has the same transferability as WM. Research with multilingual children (Engel & Gathercole, 2012) reported that executive processes measured by complex span tasks such as counting recall and backwards digit recall were related across three languages, pointing to potential cross-language transfer between WM and suppressing ability.

Research Question and Hypotheses

Study Two clarified the cross language effect of WM over reading comprehension by specifically focusing on the suppressing performance of PI. (1) A within-language relationship was expected between WM and suppressing performance in L1 and L2. Cross language transfers were hypothesised in (1) L1 WM and L2 PI performance, and (2) L2 WM and L1 PI performance.

Methodology

Participants

The same group of participants as in Study One were accepted for PI tasks, including 46 local undergraduates and postgraduates (17 males, 29 females). They were qualified as a bilingual according to the same criteria as previously.

Material and Procedures

Participants were asked to perform three PI tasks, of which two were 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. The current PI paradigm from a study (Pimperton & Nation, 2010) was modified. The PI task was designed in the E-prime programme (Schneider, Eschman, & Zuccolotto, 2001) to test the ability to suppress irrelevant information from WM. Participants were first presented with instructions on a computer screen. They were asked to identify whether a target word had been presented in the latest block of words. After the instructions, there were five practice trials for procedural familiarisation. The task was comprised of 24 trials under three conditions, commenced in random order. The word stimuli were shown in black at the centre 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 at the centre of the screen for 1000 ms, participants were sequentially shown 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. jewellery) and a target word (i.e. ring). [e.g. Was the jewellery 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 followed by two sets of five digits and a question. The cross suggests that participants should forget what they saw previously and retain the coming four words to answer the question. Participants were instructed to press labelled keys for "yes" or "no". The next trial proceeds only if a response was made.

Sixteen double block trials were divided into eight non-interference trials and eight interference trials. An interference trial is different from a 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 and the second was a target. Questions in this condition were asked with a foil word with the categorical cue, to which the correct answers were negative to suggest no PI occurred. Nevertheless, questions in non-interference trials were asked for word identification in the second block without semantic interference. PI can thus be contrasted between non-interference trial and interference trial with a controlling design in the former, but not the latter. Target words do not appear in half the single block and non-interference trials. The correct answers to these trials were half positive and half negative.

The words from the previous study were selected from the 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 use per million words. Secondly, all the words were 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 the 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 the 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, presenting method and duration as the English version of PI task. The only difference is the text material. Each word block was aggregated from 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 a magazine?]

The stimuli were chosen from the dictionary (Chinese National Language Committee, 1998), from words which are commonly known in daily life. The same semantic groups in the English PI task were selected, but, the stimuli was not the same as those in the English PI task to avoid memory transfer across languages. Randomisation in the semantic groups to three conditions was also complemented.

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

The single block trials were added to keep participants focused on the first block of stimuli. Along 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 appeared for 1000 ms followed by a question face. The question mark suggests a question about whether the following face had appeared in the block or not. A response was required before continuing. Participants pressed keyboard labels for "yes" or "no". 20 double block trials had the same structure for the first block followed by a cross, which indicates that 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.

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

The Face-Place Face Database provides the neutral facial stimuli in needed in this task. (Tarr, 2007). All faces are photographically shown in coloured format. Randomisation over races and presenting sequences were implemented to produce each block of three faces. Each block must consist of one Asian, one African and one Caucasian face. The gender of the faces was also randomly arranged in blocks. The primacy and recency effects were prevented by placing the target face in the middle of a block.

Results

PI tasks measuring the ability to suppress irrelevant information involve the central executive in the model of working memory. Accuracy and reaction time was captured to indicate the ability. There was a 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 the confounding effect from phonological STM, the performance of single block trials was excluded. The means of accuracy and reaction time of double block trials in different languages were calculated. The mean accuracy in the L1 PI task (M = 0.9, SD = 0.14) is similar to the L2 PI task (M = 0.89, SD = 0.12). The L1 PI task takes more time (M = 1556.05, SD = 592.68) than the 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

Variables	*M*	*SD*
L1 Accuracy	0.9	0.14
L1 Reaction Time (ms)	1556.05	592.68
L2 Accuracy	0.89	0.12
L2 Reaction Time (ms)	1288.09	463.64

Employing the mean PI accuracy and reaction time, a correlational analysis (see Table 5) revealed that there was positive relationship between L1 WM and L1 mean PI accuracy in double block trials, $r(43) = .36$, $p < .05$. Having controlled for 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

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Age	1										
2. Raven	.09	1									
3. L1 Working Memory	-.20	.02	1								
4. L2 Working Memory	-.01	-.06	.26	1							
5. Reaction Time of Single Block Trials	.20	.01	-.19	.01	1						
6. Reaction Time of Non-interference Trials	.16	.03	-.27	-.03	.84**	1					
7. Reaction Time of Interference Trials	.08	.07	-.25	-.05	.67**	.84**	1				
8. Mean Accuracy of Double Block Trials	-.46**	.20	.36*	-.14	-.24	-.18	-.19	1			
9. Mean Reaction Time of Double Block Trials	.11	.06	-.27	-.04	.77**	.94**	.97**	-.19	1		
10. Mean IES of Interference Trials	.35*	.07	-.19	.36*	.26	.33*	.46**	-.62**	.42**	1	
11. Mean IES of Double Block Trials	.35*	.00	-.38**	.08	.73**	.82**	.83**	-.64**	.85**	.69**	1

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

Table 6

Regression Statistics of L1 Working Memory Predicting L1 Performance of Proactive Interference Task with Age Control

Variable	Model R^2	*B*	*SE B*	β	*t*
Mean Accuracy of Double Block Trials	.28	.01	.01	.28	2.08*
Mean IES of Double Block Trials	.23	-82.35	34.8	-.33	-2.37*

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

There was a negative relationship 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) that 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

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Age	1										
2. Raven	.09	1									
3. L1 Working Memory	-.20	.02	1								
4. L2 Working Memory	-.01	-.06	.26	1							
5. Reaction Time of Single Block Trials	.22	-.14	-.36*	-.24	1						
6. Reaction Time of Non-interference Trials	.19	-.11	-.33*	-.26	.84**	1					
7. Reaction Time of Interference Trials	.24	-.06	-.39**	-.14	.77**	.67**	1				
8. Mean Accuracy of Double Block Trials	.03	.26	.16	.23	-.07	-.05	.03	1			
9. Mean Reaction Time of Double Block Trials	.24	-.09	-.40**	-.21	.88**	.88**	.94**	.00	1		
10. Mean IES of Interference Trials	.27	-.07	-.47**	-.22	.60**	.50**	.73**	-.56**	.69**	1	
11. Mean IES of Double Block Trials	.22	-.18	-.44**	-.27	.84**	.84**	.85**	-.38**	.92**	.86**	1

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

Table 8

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

Variable	*B*	*SE B*	*β*	*t*
Mean Reaction Time of Double Block Trials	-53.09	18.46	-.40	-2.88**
Mean IES of Interference Trials	-116.91	32.91	-.47	-3.55**
Mean IES of Double Block Trials	-68.60	21.29	-.44	-3.22**

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

The above result addresses overall performance of PI task. The PI paradigm possibly introduced a speed-accuracy trade-off in the performance. Some studies have proposed that statistical bias may occur when considering only reaction time or accuracy. Accordingly, the Inverse Efficiency Score (IES) was adopted to summarise the PI performance, integrating accuracy and reaction time. Dividing the mean reaction time by mean accuracy results in IES. Subsequently, IESs of interference trials in L1 and L2 were used in a correlational analysis and it was found that there is a significant relationship 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, $R^2 = .22$, $F(1, 44) = 12.62$, $p < .01$. A positive relationship 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

Variable	Model R^2	*B*	*SE B*	*β*	*t*
Step 1	.12				
Age		158.96	64.639	.35	2.46*
Step 2	.26				
Age		160.06	60.21	.35	2.66*
L2 Working Memory		339.46	123.49	.37	2.75**

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

Regression analysis further suggested the predictability of L1 WM to mean IES of double block trials in L1 and L2 (see Table 6 & 8). Among the L1 WM and L1 mean IES of double block trials, moderate coefficients after controlling for age indicate the 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, $\beta = -.44$, $t(45) = -3.22$, $p < .01$, $R^2 = .19$, $F(1, 44) = 10.39$, $p < .01$.

Discussion

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

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

The result is reasonable for the lack of within language relationship in L2, considering that 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 in the WM and suppressing tasks (Shi, & Sánchez, 2011). The 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 the current findings of within language relationships. The role of language familiarity in bilingual tasks provides a potential explanation for the findings of within language relationships in L1 WM and suppressing performance, and missing relationships yet well-supported within language effect in L2 WM and suppressing performance.

The second and third hypotheses were formulated to examine a specific mechanism underlying reading comprehension – the ability to suppress irrelevant information. The second hypothesis suggested that L1 WM predicts reaction time in the PI task in L2, whereas the third hypothesis proposed that L2 WM predicts reaction time to the PI task in L1. Surprisingly, the bilingual relationship between WM and performance in the PI task was totally opposite to the bilingual relationship between WM and reading comprehension. This may be explained by referring to the capacity and efficiency of WM which differs across languages.

The second hypothesis was mainly supported by a negative correlation between L1 WM and mean reaction time in L2 double block trials, indicating a connection between PI and resource coordination between two subcomponents of the phonological loop in the model of working memory: phonological store and articulatory rehearsal. Since L1 has advantages in earlier development and common practice, the WM of bilinguals is likely to be shaped to deal with the heavy demand of linguistic characteristics in L1 (Lee, Kim, & Zoh, 1996). The 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, the greater the influence of the language on suppression 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 is a possible cause of executive efficiency of bilingualism in the verbal domain (Robert et al., 2009).

The performance of PI, as analysed 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 greater capacity and efficiency, predicts suppressive ability in general, however, the 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 trade-off elicited by variables of accuracy and reaction time in behavioural measures (Bruyer & Brysbaert, 2011).

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

General Discussion and Conclusion

Executive Processes for Working Memory and Comprehension in Two Languages

There are two directions in which WM exerts influence. First, 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. Demand for WM due to linguistic characteristics is thus argued to be a distinction between L1 and L2, as is the effect of transition to reading comprehension.

The second effect of the transition of WM is horizontally examined in Study Two, in which both WM and PI tasks adopted the same level of linguistic unit for further processes. Addressing the capacity and efficiency of WM in L1 and L2 has been argued to be related to overall suppressive ability across languages which is commonly known to be included in reading comprehension. The effect of WM in suppressing ability and reading comprehension is partially demonstrated by the study.

Conclusion

The study attempted to identify the interactions between WM and reading comprehension, and suppressing ability in L1 and L2. First, L2 WM and L1 reading comprehension was found in adult bilinguals in Hong Kong. It extended across language influences from adolescence to adulthood and enriches bilingual literature in Chinese. Second, the relationships of WM and suppressing ability support the implicit influence of WM and reading comprehension. As one of the underlying processes 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.

Limitations and Future Research

There are shortcomings in the study. First, the study targeted adults as the sample to investigate the relationship between WM, reading comprehension and informational suppression. Due to the 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 were designed on our own. Relatively low reliability was captured in measures of English reading comprehension, which means reservations in the interpretation of data. Third, the tests were administered in two separate one-hour sessions. Some participants requested that the sessions be conducted successively, and so fatigue effect may have affected test performance. The effect may also have affected other participants who reported exhaustion as well. Fourth, IES was used to reflect general performance in PI tasks. The scores should be considered with caution, as progressively more research indicated that there may be more complex mathematical issues to be solved in managing data about accuracy and reaction time. No relationship was found between performance in PI tasks and reading comprehension. This lack of a relationship blocks the way for a further delineation of interaction between WM, suppressing ability and reading comprehension.

Further studies are encouraged to consider the relationships of the verbally analytical processes included in reading comprehension and WM. A theoretical discussion of structures and functions of WM in Hong Kong bilinguals enriches the literature from studies of distinctive linguistic characteristics to cognitive abilities. General executive function is not only present in languages but also other domains such as mathematics and perceptual learning, and 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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References

Alptekin, C., & Erçetin, G. (2010). The role of L1 and L2 working memory in literal and inferential comprehension in L2 reading. *Journal of Research in Reading, 33*(2), 206-219. doi:http://dx.doi.org/10.1111/j.1467-9817.2009.01412.x

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. Bower (ed.), *The Psychology of Learning and Motivation Vol. VIII* (New York, NY: Academic Press), pp. 47-89.

Baddeley, A. D., & Logie, R. H. (1999). Working memory: The multiple component model. In A. Miyake and P. Shah (eds), *Models of Working Memory* (New York, NY: Cambridge University Press), pp. 28-61.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities, 43*(6), 541-552. doi:http://dx.doi.org/10.1177/0022219410371676

Bruyer, R., & Brysbaert, M. (2011). Combining speed and accuracy in cognitive psychology: Is the inverse efficiency score (IES) a better dependent variable than the mean reaction time (RT) and the percentage of errors (PE)? *Psychologica Belgica, 51*(1), 5-13. doi:http://dx.doi.org/10.5334/pb-51-1-5

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*(1), 31-42. doi:http://dx.doi.org/10.1037/0022-0663.96.1.31

Cantor, J., & Engle, R. W. (1993). Working-memory capacity as long-term memory activation: An individual-differences approach. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(5), 1101-1114. doi:http://dx.doi.org/10.1037/0278-7393.19.5.1101

Cheung, H., Chan, M., & Chong, K. (2007). Use of orthographic knowledge in reading by Chinese-English bi-scriptal children. *Language Learning, 57*(3), 469-505. doi:http://dx.doi.org/10.1111/j.1467-9922.2007.00423.x

Chiappe, P., Siegel, L. S., & Hasher, L. (2002). Working memory, inhibition and reading skill. (pp. 30-51) Nova Science Publishers, Hauppauge, NY.

Chik, P. P., Ho, C. S., Yeung, P., Wong, Y., Chan, D. W., Chung, K. K., & Lo, L. (2012). Contribution of discourse and morphosyntax skills to reading comprehension in Chinese dyslexic and typically developing children. *Annals of Dyslexia, 62*(1), 1-18. doi:http://dx.doi.org/10.1007/s11881-010-0045-6

Chinese National Language Committee. (1998). *Xun xi chu li yong GB13000.1 zi fu ji: Hanzi bu jian gui fan* [Information processing using GB13000.1 character symbol anthology: Hanzi bujian analyses]. Beijing, China: Beijing Language Institute Press.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior, 19*(4), 450-466. Retrieved from http://search.proquest.com/docview/616528436?accountid=10134

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review, 3*(4), 422-433. Retrieved from http://search.proquest.com/docview/618892134?accountid=10134

Donkin, C., Brown, S., & Heathcote, A. (2011). Drawing conclusions from choice response time models: A tutorial using the linear ballistic accumulator. *Journal of Mathematical Psychology, 55*(2), 140-151. doi:http://dx.doi.org/10.1016/j.jmp.2010.10.001

Engel, d. A., & Gathercole, S. E. (2012). Executive and phonological processes in second-language acquisition. *Journal of Educational Psychology, 104*(4), 974-986. doi:http://dx.doi.org/10.1037/a0028390

García-Madruga, J. A., Elosúa, M. R., Gil, L., Gómez-Veiga, I., Vila, J. Ó., Orjales, I., . . . Duque, G. (2013). Reading comprehension and working memory's executive processes: An intervention study in primary school students. *Reading Research Quarterly, 48*(2), 155-174. Retrieved from http://search.proquest.com/docview/1417861252?accountid=10134

Glickman, M. E., Gray, J. R., & Morales, C. J. (2005). Combining speed and accuracy to assess error-free cognitive processes. *Psychometrika, 70*(3), 405-425. doi:http://dx.doi.org/10.1007/s11336-002-0999-3

Goff, D. A., Pratt, C., & Ong, B. (2005). The relations between children's reading comprehension, working memory, language skills and components of reading decoding in a normal sample. *Reading and Writing, 18*(7-9), 583-616. doi:http://dx.doi.org/10.1007/s11145-004-7109-0

Gottardo, A., Chiappe, P., Yan, B., Siegel, L., & Gu, Y. (2006). Relationships between first and second language phonological processing skills and reading in Chinese-English speakers living in English-speaking contexts. *Educational Psychology, 26*(3), 367-393. doi:http://dx.doi.org/10.1080/01443410500341098

Hashimoto, O. Y. (1972). *Phonology of Cantonese.* Cambridge, England: Cambridge University Press.

Hu, G. (2008). The misleading academic discourse on Chinese-English bilingual education in china. *Review of Educational Research, 78*(2), 195-231. doi:http://dx.doi.org/10.3102/0034654307313406

Jerman, O., Reynolds, C., & Swanson, H. L. (2012). Does growth in working memory span or executive processes predict growth in reading and math in children with reading disabilities? *Learning Disability Quarterly, 35*(3), 144-157. Retrieved from http://search.proquest.com/docview/1114699653?accountid=10134

Keung, Y., & Ho, C. S. (2009). Transfer of reading-related cognitive skills in learning to read Chinese (L1) and English (L2) among Chinese elementary school children. *Contemporary Educational Psychology, 34*(2), 103-112. doi:http://dx.doi.org/10.1016/j.cedpsych.2008.11.001

Kolić-Vehovec, S., & Bajšanski, I. (2007). Comprehension monitoring and reading comprehension in bilingual students. *Journal of Research in Reading, 30*(2), 198-211. doi:http://dx.doi.org/10.1111/j.1467-9817.2006.00319.x

Kondo, H., Morishita, M., Ashida, K., Otsuka, Y., & Osaka, N. (2003). Reading comprehension and working memory: Structural equation modeling approach. *Japanese Journal of Psychology, 73*(6), 480-487. Retrieved from http://search.proquest.com/docview/620032002?accountid=10134

Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology, 108*(3), 677-692. doi:http://dx.doi.org/10.1016/j.jecp.2010.11.001

Lee, B. T., Kim, K. J., & Zoh, M. H. (1996). Working memory and language: Comprehension individual differences in reading span and language processing. *Korean Journal of Experimental & Cognitive Psychology, 8*(1), 59-85. Retrieved from http://search.proquest.com/docview/619359022?accountid=10134

Leong, C. K., Tse, S. K., Loh, K. Y., & Hau, K. T. (2008). Text comprehension in Chinese children: Relative contribution of verbal working memory, pseudoword reading, rapid automatized naming, and onset-rime phonological segmentation. *Journal of Educational Psychology, 100*(1), 135-149. doi:http://dx.doi.org/10.1037/0022-0663.100.1.135

Li, G. (2008). Review of bilingual education in China: Practices, policies and concepts. *Studies in Second Language Acquisition, 30*(4), 547-548. Retrieved from http://search.proquest.com/docview/621628107?accountid=10134

Li, T., McBride-Chang, C., Wong, A., & Shu, H. (2012). Longitudinal predictors of spelling and reading comprehension in Chinese as an L1 and English as an L2 in Hong Kong Chinese children. *Journal of Educational Psychology, 104*(2), 286-301. doi:http://dx.doi.org/10.1037/a0026445

Lin, P., & Luck, S. J. (2012). Proactive interference does not meaningfully distort visual working memory capacity estimates in the canonical change detection task. *Frontiers in Psychology, 3*doi:http://dx.doi.org/10.3389/fpsyg.2012.00042

Lin, D., Wong, K. K., & McBride-Chang, C. (2012). Reading motivation and reading comprehension in Chinese and English among bilingual students. *Reading and Writing, 25*(3), 717-737. doi:http://dx.doi.org/10.1007/s11145-011-9297-8

Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2013). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review,* doi:http://dx.doi.org/10.3758/s13423-013-0565-2

Lipka, O., & Siegel, L. S. (2010). The improvement of reading skills of L1 and ESL children using a response to intervention (RtI) model. *Psicothema, 22*(4), 963-969. Retrieved from http://search.proquest.com/docview/816392026?accountid=10134

Liu, K., & Shen, H. (1977). Effects of language structure and intertrial interval on the speed of silent reading. *Acta Psychologica Taiwanica, 19*, 57-59. Retrieved from http://search.proquest.com/docview/616318754?accountid=10134

Loosli, S. V., Rahm, B., Unterrainer, J. M., Weiller, C., & Kaller, C. P. (2014). Developmental change in proactive interference across the life span: Evidence from two working memory tasks. *Developmental Psychology, 50*(4), 1060-1072. Retrieved from http://search.proquest.com/docview/1463026250?accountid=10134

Low, P. B., & Siegel, L. S. (2005). A comparison of the cognitive processes underlying reading comprehension in native English and ESL speakers. *Written Language and Literacy, 8*(2), 207-231. doi:http://dx.doi.org/10.1075/wll.8.2.09low

Masson, M. E., & Miller, J. A. (1983). Working memory and individual differences in comprehension and memory of text. *Journal of Educational Psychology, 75*(2), 314-318. doi:http://dx.doi.org/10.1037/0022-0663.75.2.314

Masterson, J., Dixon, M., & Stuart, M. (2002). Children's printed word database. http://www.essex.ac.uk/psychology/cpwd/.

Naumann, J., Richter, T., Christmann, U., & Groeben, N. (2008). Working memory capacity and reading skill moderate the effectiveness of strategy training in learning from hypertext. *Learning and Individual Differences, 18*(2), 197-213. doi:http://dx.doi.org/10.1016/j.lindif.2007.08.007

Otsuka, Y., Morishita, M., Kondo, H., & Osaka, N. (2003). Relationship between reading comprehension and inhibitory mechanism in working memory. *The Japanese Journal of Psychonomic Science, 21*(2), 131-136. Retrieved from http://search.proquest.com/docview/619982645?accountid=10134

Osaka, M. & Osaka, N. (1992). Language-independent working memory as measured by Japanese and English reading span tests. *Bulletin of the Psychonomic Society*, 30, 287-289.

Peng, P., Sha, T., & Li, B. (2013). The deficit profile of working memory, inhibition, and updating in Chinese children with reading difficulties. *Learning and Individual Differences, 25*, 111-117. doi:http://dx.doi.org/10.1016/j.lindif.2013.01.012

Pimperton, H., & Nation, K. (2010). Suppressing irrelevant information from working memory: Evidence for domain-specific deficits in poor comprehenders. *Journal of Memory and Language, 62*(4), 380-391. doi:http://dx.doi.org/10.1016/j.jml.2010.02.005

Proctor, C. P., Silverman, R. D., Harring, J. R., & Montecillo, C. (2012). The role of vocabulary depth in predicting reading comprehension among English monolingual and Spanish–English bilingual children in elementary school. *Reading and Writing, 25*(7), 1635-1664. doi:http://dx.doi.org/10.1007/s11145-011-9336-5

Ramirez, G., Chen, X., Geva, E., & Luo, Y. (2011). Morphological awareness and word reading in english language learners: Evidence from Spanish- and Chinese-speaking children. *Applied Psycholinguistics, 32*(3), 601-618. doi:http://dx.doi.org/10.1017/S0142716411000233

Raven, J. C. (1938). *Progressive matrices: A perceptual test of intelligence, 1938, sets A, B, C, D, and E.* London: H. K. Lewis.

Robert, C., Borella, E., Fagot, D., Lecerf, T., & De Ribaupierre, A. (2009). Working memory and inhibitory control across the life span: Intrusion errors in the reading span test. *Memory & Cognition, 37*(3), 336-345. doi:http://dx.doi.org/10.3758/MC.37.3.336

Rupp, A. A., Ferne, T., & Choi, H. (2006). How assessing reading comprehension with multiple-choice questions shapes the construct: A cognitive processing perspective. *Language Testing, 23*(4), 441-474. doi:http://dx.doi.org/10.1191/0265532206lt337oa

San Francisco, A. R., Carlo, M., August, D., & Snow, C. E. (2006). The role of language of instruction and vocabulary in the English phonological awareness of Spanish-English bilingual children. *Applied Psycholinguistics, 27*(2), 229-246. doi:http://dx.doi.org/10.1017/S0142716406060267

Savage, R., Cornish, K., Manly, T., & Hollis, C. (2006). Cognitive processes in children's reading and attention: The role of working memory, divided attention, and response inhibition. *British Journal of Psychology, 97*(3), 365-385. doi:http://dx.doi.org/10.1348/000712605X81370

Schneider, W., Eschman, A., & Zuccolotto, A. (2001). *E-Prime User's Guide.* Pittsburgh: Psychology Software Tools.

Seigneuric, A., & Ehrlich, M. (2005). Contribution of working memory capacity to children's reading comprehension: A longitudinal investigation. *Reading and Writing, 18*(7-9), 617-656. doi:http://dx.doi.org/10.1007/s11145-005-2038-0

Shi, L., & Sánchez, D. (2011). The role of word familiarity in Spanish/English bilingual word recognition. *International Journal of Audiology, 50*(2), 66-76. doi:http://dx.doi.org/10.3109/14992027.2010.527862

So, L. K. H., & Dodd, B. J. (1995). The acquisition of phonology by Cantonese-speaking children. *Journal of Child Language,22*(3), 473-495. Retrieved from http://search.proquest.com/docview/618801218?accountid=10134

Taguchi, N. (2008). The effect of working memory, semantic access, and listening abilities on the comprehension of conversational implicatures in L2 English. *Pragmatics & Cognition, 16*(3), 517-539. doi:http://dx.doi.org/10.1075/p&c.16.3.05tag

Tarr, M. J. (2007). Face-place face database (Release 2.0) [Image files].

<http://www.face-place.org/> Retrieved 12 .12 .13.

Tse, S. (1982). The acquisition of phonology: English versus Cantonese. *Acta Psychologica Taiwanica, 24*(1), 1-7. Retrieved from http://search.proquest.com/docview/617011388?accountid=10134

Wang, M., Yang, C., & Cheng, C. (2009). The contributions of phonology, orthography, and morphology in Chinese-English biliteracy acquisition. *Applied Psycholinguistics, 30*(2), 291-314. doi:http://dx.doi.org/10.1017/S0142716409090122

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *Comprehensive test of phonological processing.* Austin, TX: PRO-ED.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III Tests of Cognitive Abilities.* Itasca, IL: Riverside Publishing.

Yeung, P., Ho, C. S., Chan, D. W., Chung, K. K., & Wong, Y. (2013). A model of reading comprehension in Chinese elementary school children. *Learning and Individual Differences, 25*, 55-66. doi:http://dx.doi.org/10.1016/j.lindif.2013.03.004

Zhang, J., McBride-Chang, C., Tong, X., Wong, A. M., Shu, H., & Fong, C. Y. (2012). Reading with meaning: The contributions of meaning-related variables at the word and subword levels to early Chinese reading comprehension. *Reading and Writing, 25*(9), 2183-2203. doi:http://dx.doi.org/10.1007/s11145-011-9353-4

Zhiqiang, Q., Donling, P., Xiangjie, X., & Hengchao, L. (2009). A research on the switching process of Chinese-English bilinguals in language production and comprehension. *Psychological Science (China), 32*(2), 356-359. Retrieved from http://search.proquest.com/docview/621970074?accountid=10134

Zhong, Y., McBride-Chang, C., & Ho, C. S. (2002). A study of the relation between phonological and orthographic processing and Chinese character reading of bilingual children in Hong Kong. *Psychological Science (China), 25*(2), 173-176. Retrieved from http://search.proquest.com/docview/619731263?accountid=10134

Zhou, X., Marslen-Wilson, W., Taft, M., & Shu, H. (1999). Morphology, orthography, and phonology in reading Chinese compound words. *Language and Cognitive Processes, 14*(5-6), 525-565. doi:http://dx.doi.org/10.1080/016909699386185