ROLE OF WORKING MEMORY AND TEXT COHERENCE IN CHINESE TEXT COMPREHENSION

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ABSTRACT

The purpose of this study was to examine the relationship between working memory and text coherence in Chinese text comprehension. Eighty-six subjects were asked to complete an operation-character working memory span task to classify them into low-span and high-span and a reading task to measure the time to detect inconsistency as well as their accuracy of recall. From the results, high-span readers took less time to detect inconsistency and had better recall, whereas low-span readers took longer time to detect inconsistency and had more memory distortions. In addition, readers took more time to read passages with coherence breaks and distorted more and substituted more information in passages with coherence breaks. However, coherence breaks did not facilitate their recall as has been suggested by previous researchers.

INTRODUCTION

It is not uncommon to find readers who know all the words and grammar structures of a text, yet fail to integrate these components into text comprehension. In addition to an understanding of words and grammar, readers should be able to identify relations between the various parts of the text, as well as between the text and their world knowledge. Comprehension is, therefore, conceived as the creation of a coherent mental representation of a text (e.g., Gernsbacher, 1991; Kintsch, 1998; Van Den Broek, 1994). This coherent representation is maintained at both the local level (relations between the various parts of the text) and the global level (relations between the text and world knowledge).

From Coherence to Comprehension: An Overview of Theory and Method

Maintaining local coherence requires the reader to integrate the currently processed information with the immediately preceding context stored in working memory, whereas maintaining global coherence requires the reader to integrate the currently processed information with contextually relevant information presented earlier but that is no longer stored in working memory (e.g., Albrecht & O'Brien, 1993; McKoon & Ratcliff, 1992; O'Brien & Albrecht, 1992; O'Brien, Rizzella, Albrecht, & Halleran, 1998). There are two general views of how a reader may maintain local and global coherence: the minimalist hypothesis and constructionist hypothesis.

According to the minimalist hypothesis (e.g., McKoon & Ratcliff, 1992), readers are primarily concerned with maintaining local coherence, and they establish global coherence only when local coherence fails. On this theory, readers establish connections between the currently processed information and propositions that are in working memory. They will only establish connections between the currently processed information and information from long-term memory when there is a local coherence break or when global information (world knowledge) is readily available.

McKoon and Ratcliff (1992) tested this hypothesis by having subjects read passages that were either globally or locally inconsistent. The experimental texts were made up of an introduction and two different continuations. The introductions described some goal for the main protagonist of the story. In the control continuation, the goal was fulfilled and a new goal described. In the problematic continuation, some issue that prevented attainment of the original goal was described, and then a new goal was substituted. In the globally inconsistent passages, the new goal was inconsistent with the original goal, and the substituted goal could not lead to achievement of the original goal. In the locally inconsistent passages, the substituted goal was consistent with the original goal but the relation between the problem and the substituted goal could not easily be determined at a local level. Recognition times to global goal information following inconsistent passages were faster, but only when there was a local coherence break. Therefore, McKoon and Ratcliff concluded that readers do not automatically establish or maintain global coherence.

In contrast, the constructionist hypothesis proposed by O'Brien and colleagues has argued that readers routinely check and maintain coherence at both a local and global level. O'Brien and Albrecht (1992) had subjects read texts describing a protagonist as being at a certain location. Following several filler sentences, a target sentence described the protagonist as moving in a direction that was either consistent or inconsistent with this location. Despite the fact that the target sentence always made sense in the context of the immediately preceding sentences, reaction times increased when the location information in the target sentence conflicted with previously presented location information. This suggests that readers are able to detect the inconsistent location information, and they are concerned with integrating the information at both a local and a global level.

In a supporting study, Albrecht and O'Brien (1993) had subjects read passages that described a specific characteristic of a protagonist. After several background sentences, readers were presented with a target sentence that was either consistent or inconsistent with respect to the characteristic described earlier. Despite the fact that the target sentence always made sense with the preceding sentences, reaction times were significantly longer when it was inconsistent with the earlier described characteristic of the protagonist than when it was consistent. Similar results have also been found in studies of Chinese reading (Chow, Chan, Song, & Chen, 2000; Wang & Mo, 2001).

Hakala and O'Brien (1995) further noted that the reading times were longer no matter whether the coherence breaks were global (six sentences included between the inconsistent elaboration and the target sentence) or local (three sentences included between the inconsistent elaboration and the target sentence). Again, this suggests that readers are able to detect the inconsistent characteristics, and they attempt to maintain global coherence even when the target sentence makes sense with the preceding sentences.

A related, but somewhat grander perspective, is the construction-integration model of text comprehension proposed by Kintsch (e.g., 1988, 1998). This model distinguishes between different levels in the representation of a text that readers construct. Two levels of understanding that are relevant here are the "text base" and the "situation model."

The construction of the text base involves the extraction of semantic information from a text in the form of an interrelated network of propositions, and involves a certain amount of inferential activity. Given the text base, readers can verify statements they have read, they can answer questions about the text, they can recall the text, and they can summarize it. Knowing the text at the level of the text base, however, does not necessarily ensure that the reader understands it at a "deeper" level. Frequently, a reader must contribute information that was not stated explicitly in the text from his or her own store of knowledge about the domain in question. Furthermore, considerable active inferencing may be required to link the text base with the reader's prior knowledge. The resulting situation model integrates the information provided by the text with prior knowledge, often reorganizing and restructuring it in terms of the reader's understanding of the "world" rather than the particular text just read. Indeed, Albrecht and O' Brien (1993) acknowledged that the construction of a textual representation requires the reader to maintain only local coherence, whereas the construction of a situation model requires the reader to maintain both a local and a global coherence.

An account of individual differences in general comprehension skill is provided by Gernsbacher's (1991) structure building framework. From this model, there are three structure building processes: laying a foundation for a mental structure, mapping coherent information onto the developing structure, and shifting to initiate a new structure when the incoming information is less coherent. Mental structures are built by enhancing the activation of relevant information while suppressing the activation of less relevant information. Less skilled readers have poor access to recently comprehended information because they shift too often from actively building one substructure to initiate another. That is, instead of continuing to map incoming information onto the structure that they are developing, less skilled readers have a tendency to shift and initiate a new substructure because they have a less efficient suppression mechanism. Information that is less relevant to the structure being developed remains activated. Since this irrelevant information could not be mapped onto the developing structure, its activation lays the foundation for a new substructure.

Although research on coherence has frequently used reaction times to study how readers react to passages with coherence breaks, there is also interest in analyzing subject's recall to understand how readers select information from passages with coherence breaks. For example, O'Brien and Myers (1985) found that memory improved when information presented in a text was unexpected. They suggested that the unexpected information produced a coherence break that readers attempted to resolve by reprocessing earlier parts of the text: When reprocessing was successful, memory improved. In contrast, Myers, Shinjo, and Duffy (1987) found that memory for text improved only if the coherence breaks were moderately difficult to resolve; whereas if integration required too much effort, memory decreased.

Albrecht and O'Brien (1993) subsequently argued that resolution of a global coherence break led to an improvement in memory. In their study, each passage was broken down into idea units and subjects were scored one point for an idea unit if their recall captured the meaning of the respective idea. They found that a greater proportion of idea units in the elaboration region and target sentence were recalled after an inconsistent elaboration. This suggested that subjects tried to integrate the inconsistent information when there was a global coherence break, and that this effort had a positive impact on memory.

Building on these initial studies, Hakala and O'Brien (1995) created coherence breaks at local and global levels by varying the distance between an elaboration and a target sentence. In the local coherence condition, the elaboration and the target sentence was separated by one to three short sentences. In the global coherence condition, six intervening sentences were inserted. In addition to the idea units, they measured the distortion units. A response was scored as a distortion unit if it contradicted the information provided in the elaboration region or the target sentence. There was an increased recall in terms of the number of idea units for the elaboration region and the target sentence with a global coherence break, whereas there were a higher number of distortion units with a local coherence break. This suggested that readers integrated the inconsistent information when the coherence break occurred at a global level, but distorted the inconsistent information when the coherence break occurred at a local level.

Text coherence breaks also have a different impact given a reader's background knowledge and reading abilities. McNamara, Kintsch, Songer, and Kintsch (1996) found that a text that was both locally and globally coherent facilitated learning in students with low domain knowledge, but not in students with high domain knowledge. Low-knowledge students consistently performed better in all measures without any coherence breaks, whereas high-knowledge students performed better on the inference and problem-solving tasks with coherence breaks, but better on the text-based questions without coherence breaks.

On the other hand, Long and Chong (2001) found that readers with high reading abilities were better able to detect local and global coherence breaks, whereas readers with low reading abilities managed to detect local coherence break but failed to detect global coherence break. That is, readers with low reading abilities took longer to read the target sentence inconsistent with the character elaboration only when there was a local coherence break.

Chinese Text Coherence

Given the specific logographic features of Chinese, the recognition of Chinese characters and the phonological representation of Chinese characters have been particularly popular research areas (e.g., Liu & Peng, 1997; Seidenberg, 1985; Tan & Perfetti, 1997; Wong & Chen, 2000; Yu & Cao, 1992; Zhang & Wang, 2001).

From an investigation of the processing of Chinese text, Siu (1986) found that Chinese reading was also affected by text coherence. Results showed that reducing incoherent ideas within a passage helped students identify and order concepts. Reducing the incoherent elements, focusing on the coherent propositions, and increasing the relevant elements by means of sentence details produced the same positive effect.

In addition, text coherence breaks also appear to have an effect on the time to read inconsistent Chinese phrases. For example, Chow, Chan, Song, and Chen (2000) showed that when background information was not obvious enough, higher order themes were not readily detected. Subjects took longer to read a target phrase inconsistent with a protagonist elaboration when the theme (the subject of the target phrase) was the same as the subject of the protagonist elaboration. This result was supported by Wang and Mo (2001), who also showed that readers took longer to read inconsistent target sentences than consistent ones.

Text Coherence and Working Memory

There is also the idea that working memory capacity is related to text integration at local and global levels (Kintsch & van Dijk, 1978). When a sentence is processed in working memory, some elements of that sentence are presumptively stored to be processed anew with the next input sentence. If a connection is found between any of the new propositions and those retained in working memory, the input is accepted as coherent with the previous text. If not, a search of previously processed information is made, or an inference process is initiated to construct a coherent connection. The formation of a coherent semantic text base at both the local and global level is constrained, then, by the limitations of working memory.

Carpenter, Miyake, and Just (1995) stated that the extent to which readers maintain global coherence depends on the ease of accessing the representational structure, as well as the reader's goals, background knowledge, and working memory capacity. Based on studies of discourse comprehension coherence, they concluded that working memory capacity is a central construct in explaining the conditions under which readers maintain both local and global coherence. Indeed, empirical evidence for the role of working memory in text integration comes from many studies of discourse comprehension, and generally, individuals with smaller working memory capacities perform worse on tasks of integration.

From a meta-analysis of studies investigating the association between working memory capacity and language comprehension ability, Daneman and Merikle (1996) argued that working memory capacity is a better predictor of performance on tests of integration than on tests of comprehension. These findings suggest that working memory plays a particularly important role in the processes of integrating ideas in discourse. The various specific tests of integration measure subjects' abilities to compute the referent for a pronoun, make inferences, monitor and revise inconsistencies, acquire new word meanings from contextual cues, and abstract themes. As an example, if working memory is important to successful comprehension, individuals with a modest working memory should be less able to keep earlier information active, and therefore should be less likely to determine the referent for a pronoun. That is, they should have deficits in the process that integrates successive ideas in discourse relative to individuals that have larger working memory capacities.

Consider the work of Daneman and Carpenter (1980), who gave subjects a series of about 150 word passages and asked them to identify the referent of the pronoun in the final sentence. The number of sentences between the last mention of the referent and the pronoun was varied. Results were that readers with larger working memory spans were better at identifying the correct referent, suggesting that a bigger capacity allows for more opportunities to integrate the pronoun with its referent.

Likewise, Masson and Miller (1983), extending Daneman and Carpenter's (1980) findings, looked to see if working memory as measured by a reading span test would be associated with the ability to draw inferences. Subjects were asked to verify inferences not actually stated in the passage but based on the integration of two statements occurring on separate pages of a story. Results suggested that working memory was indeed related to the ability to make inferences from textual information. Similarly, Engle and Conway (1998) noted that readers must have ample working memory capacity to activate relevant information and to suppress irrelevant information. They suggested that working memory capacity is especially important to comprehension when the meanings of individual phrases or words are ambiguous.

Miyake, Just, and Carpenter (1994) supported that individual differences in working memory capacity play a role if multiple meanings of an ambiguous word need to be maintained over a period of time. Both high working memory span and low working memory span readers activated multiple meanings of an ambiguous word, but only high-span readers were able to maintain all the meanings and suppress irrelevant ones. In addition, low-span readers spent more time reading the ambiguous sentences than their unambiguous counterparts, but high-span readers did not show such difference. Similar results were also previously obtained by Daneman and Carpenter (1983). In that study, readers with small spans detected ambiguous words about as often as readers with large spans, however, they did not comprehend as well as readers with large spans. It appears that readers with small spans had so much tied up in the reading itself that they had less capacity for maintaining all the meanings in working memory.

To better understand the relationship between the inference process and individual differences in working memory, Whitney, Ritchie, and Clark (1991) prepared passages containing loosely specified referents and acts such that neither the larger story nor some of the specifics could readily be inferred. Subjects were asked to report their thoughts while reading each passage, including any predictions they had made or any connections they inferred between current event and prior ones. Low span readers produced significantly more inferences than high span readers, and their inferences were distributed throughout the passage. Some low-span readers committed themselves to a particular global interpretation early in the text and forced the remaining text to fit into it, whereas other low-span readers opted for local coherence and frequently changed their global interpretations as they read, seemingly without ever being able to figure out what the entire passage was about. High span readers produced their inference toward the end of the passage, as such withholding their ideas until a final interpretation. This result suggests that readers with a higher working-memory capacity can keep their ideas more open-ended and await more information from the text, whereas readers with low working-memory capacity face a tradeoff between maintaining an overall passage representation (global coherence) and maintaining sentence-to-sentence connections (local coherence).

Studies conducted with children also concluded that limitations in working memory capacity are related to some young readers' problems in text comprehension, particularly their problems in establishing global coherence and detecting inconsistencies in the text. To investigate the relationship between working memory and text comprehension, Yuill, Oakhill, and Parkin (1989) used an anomaly resolution task. Good and poor readers heard stories describing an anomalous response but also information to resolve the anomaly. Both performed the same in resolving anomalies immediately next to requisite information. However, poor readers were worse than good readers at anomaly resolution when the anomaly and the resolving information were separated. Indeed, they did not use the additional information, or repair comprehension failures, when the load on working memory was high. In short, good readers were better able to both integrate and infer seemingly because they could store more information in working memory.

Studies on Chinese text coherence by Yang, Cui, and Chen (1999) provide yet more support. Subjects were asked to judge the consistency of main and subordinate meanings of ambiguous sentences. Results showed that readers with high working memory capacities took less time to verify the meaning of ambiguous Chinese sentences than readers with low working memory capacities. Additionally, the importance of working memory capacity in suppressing irrelevant information was supported by Wang, Shen, and Zhang (2003), who investigated the suppression of spatial location and identity of Chinese characters. Their result showed that suppression of location was not correlated with working memory capacity, but suppression of identity was significantly correlated with working memory capacity.

Measurement of Working Memory

The development of a measure of working memory capacity for the Chinese subjects in this study is theoretically grounded in a long tradition. Well before any metric was developed to gauge working memory capacity, Atkinson and Shiffrin (1968) proposed a unitary short-term store that was specialized for holding information in a speech-based code. Soon, this storage concept of short-term memory evolved to include a processing component and became “working memory” (Baddeley & Hitch, 1974). Working memory, then, represented a control system with limits on both storage and processing capacities. Baddeley (1986) further elucidated the “storage plus processing” nature of working memory in his partitioned three-component model: two modality-specific storage components and the central executive. The two storage structures are the “phonological loop” that is specialized for maintaining verbal-linguistic information, and the “visuospatial sketchpad” that is specialized for maintaining visual and spatial information. The central executive acts as an attention-control structure for the two storage components and their interaction with long-term memory.

Later, the first measure of both the storage and processing of working memory was developed by Daneman and Carpenter (1980). Assuming a task-specific view of working memory, the reading span test required subjects to read and comprehend sentences (processing) and simultaneously to remember the final word in each sentence (storage). Subjects were given sets of unrelated sentences in increasing sizes, and then questioned about the sentence to make sure the readers actually understood them. After reading the sentences, subjects were asked to name as many of the last words of the sentences as they could. Reading span was defined in terms of the number of words recalled. This test was found to be highly related with reading comprehension (e.g., Daneman & Tardif, 1987; Shah & Miyake, 1996).

However, Turner and Engle (1989) challenged Daneman and Carpenter's task-specific view of working memory. They proposed an alternative model of working memory that postulated a pool of common resources available for many different cognitive processes including language comprehension and arithmetic operations. As such, they developed the operation-word span task to measure both storage and processing. Subjects were instructed to solve a string of arithmetic operations (processing) while simultaneously trying to read and memorize a word following the operation (storage). They found that the operation task correlated with reading comprehension as highly as Daneman and Carpenter's (1980) reading span test did. They concluded that the processing required by working memory does not need to involve reading to correlate with reading ability. Turner and Engle's general view of working memory capacity was further supported by various studies (e.g., Engle, Cantor, & Carullo, 1992; Engle, Kane, & Tuholski, 1999; Kane, et al., 2004).

The present study adopted the operation-word paradigm developed by Engle and his colleagues in measuring working memory capacities. Since the subjects were Chinese, the operation-word span was changed to operation-character span. This was because Chinese characters, like English words, are the basic orthographic unit embedded with their own meanings (Perfetti & Tan, 1999). Although, in daily usage, characters usually combine with other characters to compose compound words (two-character words), all single characters are morphemes with rich meanings on their own.

The stimuli words used in such tasks (e.g., La Pointe & Engle, 1990) were typically selected according to frequency of usage in the English language, and balanced for the number of syllables. In selecting Chinese characters as the stimuli materials, character frequency but not number of syllables was observed. In part, this was because Seidenberg (1985) found that Chinese characters and English words were processed similarly based on frequency. Specifically, high-frequency characters were named equally fast, whether or not they contained phonological information; whereas low-frequency characters were named faster when they contained phonological information. Therefore, high-frequency characters were selected as stimuli materials in this study. Although the syllable is also the basic phonological unit of Chinese, the number of syllables was not taken as a criterion in choosing stimuli materials because one Chinese character represents one syllable.

Chinese adaptations of Turner and Engle's (1989) work are not new. Wang, Shen, and Zhang (2003) developed an operation span test in which Chinese subjects were asked to calculate a series of arithmetic problems and recall the last digit. Wang, Zeng, and Huo (2001) developed an operation-character span test in Chinese using characters with between 5 to 12 strokes, and with frequencies of occurrence from 150 to 400 per million. Words were taken from the Modern Chinese Word Frequency Statistical Table (National Language & Word Working Committee, & National Standard Bureau, 1992). This span test, developed in Mainland China where Mandarin and simplified Chinese writing are dominant, was not used in the present study carried out in Macao, where Cantonese and traditional Chinese writing are dominant. A new operation-character span test was then developed based on a database of Chinese character frequency compiled in Hong Kong (Humanities Computing and Methodology Program and Research Institute for the Humanities, 2002), which shares the same language and writing with Macao.

Research Summary and Hypotheses

The purpose of this study is to further examine the relationship between working memory and text coherence in Chinese text comprehension. It is hypothesized that there will be a difference between low working memory span and high working memory span readers in time to detect inconsistency and in accuracy of recall in Chinese passages with coherence breaks. Specifically, the two research questions are: (a) What are the reaction times low-span and high-span readers take in detecting inconsistency in Chinese passages with coherence breaks? (b) What do low-span and high-span readers recall from Chinese passages with coherence breaks? Following these two questions, a number of predictions can be made based on the extant literature.

Specifically, readers with high working memory span have been found to perform better in various text coherence tasks than readers with low working memory span (e.g., Daneman & Carpenter, 1980; Masson & Miller, 1983; Miyake, Just & Carpenter, 1994; Whitney, Ritchie, & Clark, 1991; Yang, Cui, & Chen, 1999). Therefore, high-span readers are expected to take less time to detect passages with coherence breaks and to recall more idea units than their low-span counterparts. Low-span readers are expected to take longer to detect passages with coherence breaks and have more memory distortion and substitution units than their high-span counterparts.

Additionally, previous studies on text coherence showed that readers took longer to read passages with coherence breaks (e.g., Albrecht & O'Brien, 1993; Chow, Chang, Song, & Chen, 2000; Hakala & O'Brien, 1995; Wang & Mo, 2001). The current study also expects readers to take longer reading passages with coherence breaks.

Studies on the recall of passages with coherence breaks have also noted that global coherence break facilitated the recall of idea units (Albrecht & O'Brien, 1993; Hakala &

O'Brien, 1995), and local coherence break elicited more distortion units (Hakala & O'Brien). The current study expects readers to recall more idea units from passages with global coherence break, and to have more distortion units from passages with local coherence break.

Unlike previous studies on passages with one protagonist, the present study used passages with two protagonists. As such, an analysis of the number of substitution units was also added in this study. A response was scored as a substitution unit if the subject of the action was substituted with the other protagonist. It is expected that the recall of substitution units will resemble the recall of distortion units. Readers are, then, expected to have more substitution units from passages with local coherence break than global coherence break.

Typically, there are five passage regions used in studies of text coherence: introduction, elaboration, filler, target sentence, and close. It has been found that the elaboration region and the target sentence are better recalled than the other passage regions (e.g., Albrecht and O'Brien, 1993; Hakala & O'Brien, 1995). Therefore, this study also expects the elaboration region and the target sentence to be better recalled.

The present study differs from previous studies in a couple of different ways. First, previous studies on Chinese text coherence (e.g., Chow, Chang, Song, & Chen, 2000; Wang & Mo, 2001) investigated the effect of consistency on reaction times, and used passages with target sentences either consistent or inconsistent with elaboration regions. In addition to the effect of consistency, the present study investigates the effect of coherence on reaction times. Also, in addition to the measure of reaction times, this study also looks at the accuracy of recall for the passages.

Second, previous studies on text coherence (e.g., Hakala & O'Brien, 1995) investigated the effect of consistency and coherence on the recall of idea units and distortion units from passages with one protagonist. Using passages with two protagonists, the present study investigates the effect of consistency and coherence on the recall of idea units, distortion units, as well as substitution units.

Third, although working memory capacity has been related to text coherence at both local and global levels (e.g., Carpenter, Miyake, & Just, 1995; Daneman & Merikle, 1996; Kintsch & van Dijk, 1978), studies on working memory and text coherence have thus far focused on the time to identify the referent of the pronoun, make inferences, detect ambiguous words and text inconsistencies (Daneman & Carpenter, 1980; Masson & Miller, 1983; Miyake, Just & Carpenter; 1994; Whitney, Ritchie, & Clark, 1991; Yuill, Oakhill, & Parkin, 1989). In addition to the measure of time to detect text inconsistencies, the present study also asks readers with different working memory capacities to recall from passages with inconsistencies at a global and local level.

METHOD

Subjects

The subjects were 86 undergraduate volunteers drawn from Pre-primary, Primary, or Secondary Education programs at the University of Macao. There were 76 females and 10 males with ages from 18 to 22. The primary language of all subjects was Cantonese. The procedures met all American Psychological Association (APA) ethical principles for use of human subjects (APA, 2002), and subjects were provided informed consent in accordance with guidelines set by the Institutional Review Board of Texas A & M University-Commerce.

Design

To test the hypothesis that there was a difference between low working memory span and high working memory span readers in time to detect inconsistency and in accuracy of recall in Chinese passages with coherence breaks, two research analyses were conducted. The first analysis examined the time taken by low-span and high-span readers to detect inconsistency in Chinese passages with coherence breaks and was a 2 (working memory) * 2 (consistency) * 2 (coherence) analysis of variance (ANOVA) on target-sentence reading times.

There were five passage regions: introduction, elaboration, filler, target sentence, and close, with the target sentence being either consistent or inconsistent with previous elaboration. The second analysis examined the recall of passages with coherence breaks in low-span and high-span readers and required three separate 2 (working memory) * 2 (consistency) * 2 (coherence) ANOVAs on the percentage of idea units, distortion units, and substitution units produced by subjects respectively. An idea unit captured the correct meaning of the respective idea of the passage, a distortion unit contradicted the information provided in the elaboration region or the target sentence, and a substitution unit changed the subject of the action from one character to the other.

Working memory (low-span and high-span) was a between-subjects factor; whereas consistency (consistent and inconsistent) and coherence (global and local) were within-subjects factors.

There were two tasks to be completed by each subject for this work: the operation-character task to classify readers into low-span and high-span and the reading task to measure the time to detect inconsistency and their accuracy of recall. The first consisted of a series of paired mathematical operations and Chinese characters. The number of pairs in a series ranged from two to seven. For each pair, there were three trials. As such, there were 81 operation-character pairs (2 pairs * 3 trials + 3 pairs * 3 trials + 4 pairs * 3 trials + 5 pairs * 3 trials + 6 pairs * 3 trials + 7 pairs * 3 trials).

The second task consisted of four Chinese passages presented in four conditions: global consistent, local consistent, global inconsistent and local inconsistent. Reaction times to detect inconsistency and recall of the passages were recorded to test whether there was a difference between low working memory span and high working memory span readers. The consistency depended on whether the target sentence was consistent or inconsistent with the previous elaboration. The coherence depended on the number of sentences at the filler region. There were usually six sentences in global coherence and one sentence in local coherence.

Materials

Operation-character span task. The operation-character span test was administered to measure working memory capacity. It included a processing task and a storage task. Subjects verified the accuracy of a mathematical operation and memorized a Chinese character, for example, Is (6/2) – 2 = 3 ? 高. The operations to be used here were initially developed by La Pointe and Engle (1990, see Appendix A).

Since Seidenberg (1985) found that phonological information encoded in a Chinese character only facilitated naming when it was low in frequency, high-frequency Chinese characters were chosen as stimuli in this study to circumvent such phonological mediation. However, based on the same standard sources of word frequency, different authors have set their own criteria of what counts as high and low frequency words (see Engle, Nations, & Cantor, 1990; Seidenberg, 1985; and also Ding, Peng, & Taft, 2004; Tan & Perfetti, 1997). In short, there is no accepted guideline on how frequent a Chinese character should be in order to be called "high-frequency." The present study chose characters with a frequency occurrence at the third quartile (50^{th} to 75^{th} percentile) because extremely frequent characters may also introduce subtle confounds when testing working memory capacity (Henley, 1990).

The database of Chinese character frequency compiled by the Chinese University of Hong Kong was used (Humanities Computing and Methodology Program, & Research Institute for the Humanities, 2002). The present study was based on the Hong Kong corpus from the 1980s - 1990s. The total number of characters was 663,463, and the number of distinctive characters from the basic character frequency statistical table was 4,628. Frequency was calculated by dividing the frequency count of a character in a corpus unit by the total number of characters in that unit, times 100%. From the third quartile of the most frequent characters, there were 122 characters with strokes ranging form 2 to 17. Since there was a total of 81 operation-character pairs, 81 characters were randomly chosen from this set as stimuli characters pool (see Appendix B).

The pairing of operation with character was also randomly generated. However, two characteristics of Chinese characters were considered as a check on the final pairings: homophones and meanings. Wang, Perfetti, and Liu (2003) pointed out that there are a large number of homophones in Chinese because the small number of syllables results in a small set of morphemes that can be uniquely represented in spoken Chinese. Likewise, characters can be combined with the other characters to form compound words with a meaning different from the constituent characters. For example, 兩 means "two," and 性 means "sex," but 兩性 means "males and females." Therefore, the following constraints were imposed in the random generation of operation-characters pairs: (a) homophones should not be included, and (b) the order of the Chinese characters should not create any literal meanings.

Reading task. Following the methods of Wang and Mo (2001), the reading passages in this study (4 of the 16 passages used by Long & Chong, 2001, Experiment 1, see Appendix C) were rewritten in Chinese. A colleague, a Professor of Bilingual Translation, was used to check both versions to make sure that the Chinese version matched the English version. There were five passage regions at each of the four passages: introduction, elaboration, filler, target sentence, and close. Each passage began with a two- to three-sentence section introducing two characters. This was followed by an elaboration that was either consistent or inconsistent with the target sentence. In the consistent conditions, Mary loved hot food (elaboration) and ordered a fried spicy chicken (target sentence). In the inconsistent conditions, Mary was a vegetarian (elaboration) but ordered a fried spicy chicken (target sentence). Filler sections followed to strain the character description in working memory. There were usually six sentences in each of the global coherence fillers, and one sentence in each of the local coherence fillers. The passages were followed by a target sentence that was either consistent or inconsistent with the earlier elaboration. Then, the story concluded with a brief closing section.

In this study, each subject read four passages in Chinese. Each of the four passages was presented in one of the four conditions: global coherence (consistent, inconsistent), local coherence (consistent, inconsistent). The consistency depended on whether the target sentence was consistent or inconsistent with the earlier elaboration. The coherence depended on the number of sentences at the filler region. The resulting sixteen conditions were counterbalanced across the four passages so that each subject was randomly assigned to all of the four conditions.

Procedures

All tasks were presented in Microsoft PowerPoint via an IBM ThinkPad T42 1.5 GHz Pentium M laptop PC with 14.1 inch screen, 30 GB Hard Drive, 256 MB RAM, and Windows XP Professional version 2002 as the operating system. To reduce glare on the computer screen, the study was conducted in a semi-darkened and quiet office furnished with one desk, two swivel chairs, one file cabinet, and one book shelf. Subjects sat approximately 50 cm from the computer screen in a single session for approximately 45 minutes. Consent forms in Chinese were given to subjects at the beginning of the session (see Appendix D), and the researcher read the instruction, explained the procedure, and answered any questions in Cantonese before each task began (see Appendix E). Next, the researcher gave three trials of two operation-character pairs and a reading passage to subjects as practice items. These were not scored and were used so that subjects could familiarize themselves with the procedures. Last, there were two experimental tasks to be completed: the operation-character task and the reading task. The task order was counterbalanced across subjects.

Operation-character span task. The procedure for presenting the operation-character span task was adapted from the automatic operation span (Schrock, Unsworth, & Heitz, 2003). The operation and the Chinese characters were presented in black against a white background in a 44-point font. Since La Pointe and Engle (1990) found out that subjects' oral reading rate while reading aloud demonstrated no significance, the present study did not require the subjects to read aloud.

At the beginning of a trial, a "+" sign was presented at the center of the computer screen for 1 second, followed by a blank screen for another 1 second. Then, a mathematical operation appeared, and subjects were instructed to begin mentally calculating it immediately (e.g., [(6 × 2) – 5 = ?]). When subjects had calculated their own answers, they pressed the "enter" key on the keyboard to proceed to the next screen. An answer for the operation would then be given on the screen, and subjects verified whether it was correct by indicating "True" or "False." Subjects were asked to perform the operation verification as quickly as possible, but to be accurate. Then, they pressed "enter" to move onto the next screen to show a Chinese character for 1 second and to memorize it for recall later. The screen was blank for 1 second, followed by either another operation-character pair or the recall cue (a set of three question marks) at the center of the screen. The question marks signaled the subjects to write down in the correct order the preceding Chinese characters. Subjects were asked to refrain from writing down the last character first. Guessing was encouraged, and recall was not timed. The number of pairs in a series ranged from two to seven. For each pair, there were three trials. As such, there were a total of 81 operation-character pairs. Pairs varied in random order for each subject, so that subjects did not know the number of characters to be recalled until the question marks appeared. When subjects had finished writing the characters, they pressed the "enter" key to proceed to the next new trial starting again with a "+" sign.

Reading task. The procedure for presenting the reading task was adapted from the work of Long and Chong (2001, Experiment 1). The time to read the target sentence and the response to a comprehension question of each passage were recorded.

Reading time of the target sentence was measured by the Digitest-1000, a meter used to count reaction time in milliseconds in sports science and medicine (Abrantes, Macas & Sampaio, 2004). The first press on the "start/stop" button on the Digitest-1000 activates the meter, and the second press on the “start/stop” button stops the meter. Based on pilot work, this meter was placed next to the keyboard and subjects were instructed to press the “start/stop” button on the Digitest-1000 with their dominant hand while simultaneously pressing the “enter” on the keyboard with the other hand. Each press on the “start/stop” button either started or stopped the meter, whereas each press on the “enter” key erased the current line of the passage and presented the next one. Subjects were asked to press the “start/stop” button, and the “enter” key from the first line of the passage till the last line of the comprehension question. Each passage was presented in a way that subjects started the meter when they read the target sentence and stopped the meter when they finished the target sentence. The researcher was able to read from the meter the target-sentence reading time and recorded it by hand.

Several previous studies used software to calculate the reaction times between key presses on a computer keyboard (e.g., Albrecht & O’Brien, 1993; Hakala & O’Brien, 1995; Long & Chong, 2001). However, with a limitation on the availability of adaptable computer equipment at the Macao facility, this study used the Digitest-1000. Although pilot work suggests a high fidelity in the methods used, it is important to note that this study was not interested in the accuracy to the millisecond for reading the target sentence, but only in the relative difference between the times subjects took to read the target sentence. As such, the methods used proved more than adequate for the task.

At the beginning of a trial, a “+” sign followed by a number of “~” characters was presented at the center of the computer screen for 1 second to control for the sentence lengths of the stimuli to come. This was followed by a blank screen for 1 second. The passages were presented one line at a time in black against a white background in a 44-point font. At the end of each passage, a close-ended question was presented to check subjects’ comprehension. Subjects were instructed to state their answers verbally, “yes” or “no,” so that the researcher could score them by hand.

When all of the four passages were read on the computer screen, subjects were given a recall booklet to write down all they could remember about each passage. Each page of the booklet provided a recall cue (the first sentence of each passage) for a particular passage. The passages were recalled in the same order that they were read. Once they had finished recalling a passage and turned the page, they could not return to the previous pages.

Analysis

Operation-character span task. The working memory span was scored with the proportion method used by Kane et al. (2004). A Chinese character was scored as correct only if it was recalled in correct serial position. The number of correct characters within the three trials of each pair was converted into a proportion-correct score, and the mean of the proportion-correct scores from the six pairs was the working memory span score.

Reading task.. The analysis of the cued recall was performed according to the method used by Albrecht and O'Brien (1993). Each passage was broken down into idea units. Subjects were given a point for an idea unit if their recall captured the meaning of the respective idea. An analysis of the number of distortions was conducted according to the method used by Hakala and O'Brien (1995). A response was scored as a distortion unit if it contradicted the information provided in the elaboration region or the target sentence. An analysis of the number of substitution units was unique to this study. A response was scored as a substitution unit if the subject of the action was substituted with the other character. The researcher and a colleague scored the recall. Interrater agreement for the idea units was 87%, for the distortion units was 93%, and for the substitution units was 94%. The discrepancies were resolved by mutual discussion. Because each passage was composed of a different number of idea units, distortion units and substitution units, all analyses were conducted on percentage data.

RESULTS

Working memory task

The 86 subjects' span scores were screened with a stem & leaf plot. Data that were more than 1.5 times the interquartile range from the upper or lower quartile were considered as outliers. Three span scores that were equal to or smaller than .48 were then excluded from the analyses. Cronbach's alpha (.77) was derived from the proportion-correct scores of the six operation-characters pairs. This index of internal consistency showed an acceptable reliability.

Descriptive statistics of the operation-character span scores (M = .801, SD = .116) showed a range from .489 to .982. The median score (.824) was used as a cutting point between high-span and low-span readers. Subjects with working memory scores equal to or below the median (.824) were classified as low-span readers and those with scores above the median were classified as high-span readers. An independent t-test showed a significant difference between low-span readers (M = .714, SD = .095) and high-span readers (M = .891, SD = .045), $t(81) = -10.807$, $p < .001$.

Descriptive statistics also showed that the error in verifying the accuracy of the operations was minimal (M = .03, SD = .033). An independent t-test showed that there was no difference between the low-span (M = .035, SD = .037) and high-span readers (M = .025, SD = .029) in verifying the accuracy of the operations, $t(81) = 1.41$. $p = .162$.

Reading task

Comprehension. Reading task recall data in which subjects produced no results for a given passage were considered as missing data. With 8 missing recall data and 3 span-scores outliers, the analysis of the comprehension questions was conducted on the remaining 75 subjects. Descriptive statistics showed that the percentage of correct answers was very high: consistent global (M = .96, SD = .197), consistent local

(M = .96, SD = .197), inconsistent global (M = .99, SD = .115), and inconsistent local (M

= .97, *SD* = .162). Independent *t*-tests showed that there was no difference between the low-span readers: consistent global (*M* = .95, *SD* = .223), consistent local (*M* = 1, *SD* = 0), inconsistent global (*M* = .97, *SD* = .16) and inconsistent local (*M* = .95, *SD* = .223); and high-span readers: consistent global (*M* = .97, *SD* = .167), *t*(73) = -.513, *p* = .61, consistent local (*M* = .92, *SD* = .28), *t*(73) = 1.858, *p* = .067, inconsistent global (*M* = 1, *SD* = 0), *t*(73) = -.96, *p* = .34, and inconsistent local (*M* = 1, *SD* = 0), *t*(73) = -1.376, *p* = .173, in answering the comprehension questions.

Reaction times. All latencies of 86 reaction times were screened with the stem & leaf plot for outliers which were more than 1.5 times the interquartile range from the upper or lower quartile. Twelve outliers were screened. In addition to the 3 outliers of the span scores, 15 subjects were excluded and thus 71 subjects were used. The mean reaction times at different passage conditions for readers with different working memory span are presented in Table 1.

Table 1

Mean Reading Times (in Seconds) for Target Sentence as a Function of Passage Conditions and Working Memory Span

		Consistent		Inconsistent		
Working Memory		Global	Local	Global	Local	Total
Low-span	*M*	2.155	1.976	2.146	2.263	2.135
n=36	*SD*	.696	.527	.595	.642	.615
High-span	*M*	1.838	1.788	2.008	1.898	1.883
n=35	*SD*	.61	.625	.615	.658	.627
Total	*M*	1.999	1.883	2.078	2.083	2.011
N=71	*SD*	.67	.581	.605	.671	.632

ANOVAs showed that there were significant main effects of passage conditions, $F(3, 207) = 2.797$, $p = .041$, and working memory span, $F(1, 69) = 5.081$, $p = .027$. To analyze the main effects of passage conditions and working memory span, Bonferroni's procedure was used to compare the group means. The mean times taken to read the target sentence in the inconsistent local condition ($M = 2.083$ s, $SD = .671$) was significantly longer than those in the consistent local condition ($M = 1.883$ s, $SD = .581$). A paired *t*-test showed that readers took longer to read the target sentence in the inconsistent conditions ($M = 2.081$ s, $SD = .526$) than in the consistent conditions ($M = 1.941$ s, $SD = .55$), $t(70) = -2.513$, $p = .014$. Simple effect analyses showed no times differences for low-span and high-span readers among the different passage conditions.

Bonferroni's procedure also showed that low-span readers took significantly longer to read the target sentence ($M = 2.135$ s, $SD = .615$) than high-span readers ($M = 1.883$ s, $SD = .627$). Simple effect analysis showed that low-span readers took significantly longer to read the target sentence ($M = 2.155$ s, $SD = .696$) than high-span readers ($M = 1.838$ s, $SD = .61$) in the consistent global condition. Low-span readers also took significantly longer to read the target sentence ($M = 2.263$ s, $SD = .642$) than high-span readers ($M = 1.898$ s, $SD = .658$) in the inconsistent local condition. In addition, an independent *t*-test showed that low-span readers took longer ($M = 2.205$ s, $SD = .488$) than high-span readers ($M = 1.953$ s, $SD = .54$), $t(69) = -2.06$, $p = .043$ to detect the inconsistency when there were coherence breaks.

Recall. With 8 missing recall data and 3 span-scores outliers, 11 subjects were excluded and thus 75 subjects were used. Table 2 presents the mean percentage of idea units recalled for all passages conditions by low-span and high-span readers.

Table 2

Mean Percentage of Idea Units Recalled as a Function of Passage Conditions and Working Memory Span

		Consistent		Inconsistent		
Working Memory		Global	Local	Global	Local	Total
Low-span	*M*	.414	.397	.364	.422	.399
n=39	*SD*	.156	.196	.165	.172	.172
High-span	*M*	.435	.475	.451	.454	.454
n=36	*SD*	.138	.185	.167	.176	.167
Total	*M*	.424	.434	.406	.437	.425
N=75	*SD*	.147	.194	.171	.174	.172

ANOVAs showed that there was a significant main effect of working memory, $F(1, 73) = 4.173$, $p = .045$, but not of passage conditions, $F(3, 219) = .702$, $p = .552$. Bonferroni's procedure was used to compare the group means of working memory. It was shown that high-span readers recalled significantly more idea units (*M* = .454, *SD* = .167) than low-span readers (*M* = .399, *SD* = .172). Simple effect analysis showed that high-span readers recalled more idea units (*M* = .451, *SD* = .167) than low-span readers (*M* = .364, *SD* = .165) in the inconsistent global condition. There was no difference for low-span and high-span readers in recalling the idea units across different passage conditions. Further paired *t*-test showed that there was no difference between the idea units recalled in the consistent (*M* = 429, *SD* = .139) and inconsistent conditions (*M* = .421, *SD* = .143), $t(74) = .45$, $p = .654$.

To examine the idea units recalled across different passage regions in low-span and high-span readers, separate ANOVAs were performed. Table 3 presents the mean percentage of idea units recalled as a function of recall regions of the passage and working memory span.

Table 3

Mean Percentage of Idea Units Recalled as a Function of Passage Regions and Working Memory Span

Working Memory		Introduction	Elaboration	Filler	Target	Close	Total
Low-span	*M*	.402	.331	.441	.628	.193	.399
n=39	*SD*	.235	.134	.174	.256	.11	.182
High-span	*M*	.468	.392	.495	.694	.22	.454
n=36	*SD*	.219	.128	.139	.232	.126	.169
Total	*M*	.434	.361	.467	.66	.206	.425
N=75	*SD*	.228	.134	.159	.245	.118	.177

ANOVAs showed that there were significant main effects of the passage regions, $F(3.326, 242.779) = 81.787$, $p < .001$, and of working memory, $F(1, 73) = 4.173$, $p = .045$. Bonferroni's procedure was used to compare their group means. It was shown that the target sentence was the best recalled (*M* = .66, *SD* = .245); whereas the close region was the least recalled (*M* = .206, *SD* = .118). High-span readers recalled more idea units (*M* = .454, *SD* = .169) than low-span readers (*M* = .399, *SD* = .182). Simple effect analysis showed that high-span readers recalled more idea units (*M* = .392, *SD* = .128) than low-span readers (*M* = .331, *SD* = .134) at elaboration region. There was also a difference for low-span and high-span readers in recalling the idea units across different passage regions.

To further examine the idea units recalled across different passage regions at different passage conditions, paired *t*-tests were performed. Table 4 presents the mean percentage of idea units recalled as a function of passage regions and passage conditions. Results showed that the elaboration region was better recalled in the inconsistent local condition (*M* = .407, *SD* = .23) than in the inconsistent global condition, (*M* = .34, *SD* = .227), $t(74) = -2.008$, $p = .048$.

Table 4

Mean Percentage of Idea Units Recalled as a Function of Passage Regions and Passage Conditions

Passage Conditions		Introduction	Elaboration	Filler	Target	Close
Consistent						
Global	*M*	.446	.343	.4	.72	.212
	SD	.302	.228	.189	.452	.208
Local	*M*	.41	.353	.533	.653	.222
	SD	.335	.22	.422	.479	.231
Inconsistent						
Global	*M*	.439	.34	.38	.667	.203
	SD	.345	.227	.199	.475	.2
Local	*M*	.44	.407	.553	.6	.186
	SD	.338	.23	.382	.493	.197

Table 5 presents the mean percentage of distortion units recalled for all passages conditions by low-span and high-span readers. ANOVAs showed that there was a significant main effect of passage conditions, $F(1.803, 131.613) = 3.227$, $p = .048$; but no main effect of working memory, $F(1, 73) = 1.872$, $p = .175$. Bonferroni's procedure was used to compare the group means of passage conditions but found no differences among them. Paired *t*-tests showed that readers recalled significantly more distortion units in the inconsistent global condition ($M = .0107$, $SD = .0352$) than in the consistent global condition ($M = .0005$, $SD =$ 0046), $t(74) = -2.465$, $p = .016$, and consistent local condition ($M = 0$, $SD = 0$), $t(74) = -2.628$, $p = .01$. They also recalled significantly more distortion units in the inconsistent local condition ($M = .0087$, $SD = .0373$) than in the consistent local condition ($M = 0$, $SD = 0$), $t(74)$

= -2.022, *p* = .047. Further paired *t*-test also showed that readers recalled more distortion units in the inconsistent conditions (*M* = .0097, *SD* = .0247) than in the consistent conditions (*M* = .0003, *SD* = .0023), *t*(74) = -3.276, *p* = .002. Simple effect analysis showed that there was a difference for low-span readers to recall distortion units across the passage conditions, but there was no difference for their high-span counterparts. In addition, there was no difference between low-span and high-span readers in recalling distortion units at the four passage conditions.

Table 5

Mean Percentage of Distortion Units Recalled as a Function of Passage Conditions and Working Memory Span

		Consistent		Inconsistent		
Working Memory		Global	Local	Global	Local	Total
Low-span	*M*	0	0	.0128	.0145	.007
n=39	*SD*	0	0	.0456	.0495	.0238
High-span	*M*	.0011	0	.0083	.0024	.003
n=36	*SD*	.0067	0	.0185	.0143	.0099
Total	*M*	.0005	0	.0107	.0087	.005
N=75	*SD*	.0046	0	.0352	.0373	.0193

To examine the distortion units recalled across different passage regions in low-span and high-span readers, *t*-tests were performed. Table 6 presents the mean percentage of distortion units recalled as a function of passage regions of the passage and working memory span.

Table 6

Mean Percentage of Distortion Units Recalled as a Function of Passage Regions and Working Memory Span

Working Memory		Introduction	Elaboration	Filler	Target	Close	Total
Low-span	*M*	0	.0085	0	.0256	0	.0068
n=39	*SD*	0	.0218	0	.0768	0	.0197
High-span	*M*	.003	.0118	0	0	0	.003
n=36	*SD*	.0179	.0239	0	0	0	.0084
Total	*M*	.0015	.0102	0	.0128	0	.0049
N=75	*SD*	.009	.0229	0	.0384	0	.0141

Independent *t*-test showed that low-span readers recalled more distortion units at the target region (*M* = .0256, *SD* = .0768) that high-span readers (*M* = 0, *SD* = 0), *t*(73) = 2.001, *p* = .049. Paired *t*-test further showed that readers recalled more distortion units at the elaboration region (*M* = .0102, *SD* = .0229) and target sentence (*M* = .0128, *SD* = .0384) than the introduction region (*M* = .0015, *SD* = .009), the filler region (*M* = 0, *SD* = 0), and the close region (*M* = 0, *SD* = 0).

To further examine the distortion units recalled across different passage regions at different passage conditions, paired *t*-tests were performed. Table 7 presents the mean percentage of distortion units recalled as a function of passage regions and passage conditions.

Table 7

Mean Percentage of Distortion Units Recalled as a Function of Passage Regions and Passage Conditions

Passage Conditions		Introduction	Elaboration	Filler	Target	Close
Consistent						
Global	*M*	0	.0027	0	0	0
	SD	0	.0231	0	0	0
Local	*M*	0	0	0	0	0
	SD	0	0	0	0	0
Inconsistent						
Global	*M*	0	.0267	0	.0267	0
	SD	0	.0777	0	.1622	0
Local	*M*	.0057	.0111	0	.0267	0
	SD	.0495	.05	0	.1622	0

Paired *t*-tests showed that elaboration region was distorted more in the inconsistent global condition (*M* = .0267, *SD* = .0777) than consistent global condition (*M* = .0027, *SD* = .0231), *t*(74) = -2.538, *p* = .013, and consistent local condition (*M* = 0, *SD* = 0), *t*(74) = -2.974, *p* = .004. Further paired *t*-tests showed that elaboration region was distorted more in the inconsistent conditions (*M* = .0189, *SD* = .0446) than consistent conditions (*M* = .0013, *SD* = .0116), *t*(74) = -3.267, *p* = .002. The target region was also distorted more in the inconsistent conditions (*M* = .0267, *SD* = .1131) than consistent conditions (*M* = 0, *SD* = 0), *t*(74) = -2.042, *p* = .045.

Table 8

Mean Percentage of Substitution Units Recalled as a Function of Passage Conditions and Working Memory Span

		Consistent		Inconsistent		
Working Memory		Global	Local	Global	Local	Total
Low-span	*M*	.023	.025	.058	.063	.042
n=39	*SD*	.063	.084	.094	.095	.085
High-span	*M*	.031	.024	.021	.066	.035
n=36	*SD*	.074	.06	.058	.0109	.051
Total	*M*	.027	.024	.04	.064	.039
N=75	*SD*	.068	.073	.08	.101	.081

Table 8 presents the mean percentage of substitution units recalled for all passages conditions by low-span and high-span readers. ANOVAs showed that there was a significant main effect of passage conditions, $F(3, 219) = 4.082$, $p = .008$; but no main effect of the working memory, $F(1, 73) = .408$, $p = .525$. Bonferroni's procedure was used to compare the group means of passage conditions. It was shown that readers recalled significantly more substitution units in the inconsistent local condition (*M* = .064, *SD* = .101) than in the consistent global (*M* = .027, *SD* = .068) and consistent local conditions (*M* = .024, *SD* = .073). Simple effect analysis showed that there was a difference for low-span readers to recall substitution units across the passage conditions, but there was no difference for their high-span counterparts. In addition, there was no difference between low-span and high-span readers in recalling substitution units across different passage conditions. Further paired *t*-test showed that readers recalled more substitution units in the inconsistent conditions (*M* = .052, *SD* = .07) than in the consistent conditions (*M* = .026, *SD* = .0512), $t(74) = -2.791$, $p = .007$.

To examine the substitution units recalled across different passage regions in low-span and high-span readers, separate ANOVAs were performed. Table 9 presents the mean percentage of substitution units recalled as a function of passage regions of the passage and working memory span.

Table 9

Mean Percentage of Substitution Units Recalled as a Function of Passage Regions and Working Memory Span

Working Memory		Introduction	Elaboration	Filler	Target	Close	Total
Low-span	*M*	.011	.023	.003	.147	.026	.042
n=39	*SD*	.048	.059	.02	.196	.04	.074
High-span	*M*	.007	.029	0	.125	.017	.035
n=36	*SD*	.042	.045	0	.164	.034	.056
Total	*M*	.009	.026	.002	.137	.022	.04
N=75	*SD*	.045	.052	.014	.181	.038	.066

ANOVAs showed that there was a significant main effect of the passage regions, $F(1.376, 100.442) = 31.626$, $p < .001$, but no main effect of the working memory, $F(1, 73) = .408$, $p = .525$. Bonferroni's procedure was used to compare the group means of passage regions. It was shown that readers recalled more substitution units at the target sentence ($M = .137$, $SD = .181$) than the introduction ($M = .009$, $SD = .045$), the elaboration ($M = .026$, $SD = .052$), the filler ($M = .002$, $SD = .014$), and the close regions ($M = .022$, $SD = .038$). Readers also recalled more substitution units at the elaboration ($M = .026$, $SD = .052$) than the filler ($M = .002$, $SD = .014$). Simple effect analysis showed that there were differences in recalling the substitution units across different passage regions for low-span and high-span readers. However, no difference was found between low-span and high-span readers in recalling the substitution units across different passage regions.

To further examine the substitution units recalled across different passage regions at different passage conditions, paired *t*-tests were performed. Table 10 presents the mean percentage of substitution units recalled as a function of passage regions and passage conditions.

Table 10

Mean Percentage of Substitution Units Recalled as a Function of Passage Regions and Passage Conditions

Passage Conditions			Introduction	Elaboration	Filler	Target	Close
Consistent							
	Global	*M*	0	.039	0	.08	.016
		SD	0	.112	0	.273	.068
	Local	*M*	.013	.021	.007	.067	.014
		SD	.115	.105	.058	.251	.061
Inconsistent							
	Global	*M*	.009	.024	0	.147	.21
		SD	.077	.085	0	.356	.074
	Local	*M*	.013	.018	0	.253	.037
		SD	.115	.077	0	.438	.094

Paired *t*-tests showed that the target sentence was substituted more in the inconsistent local condition (M = .253, SD = .438) than the consistent global condition (M = .08, SD = .273), $t(74)$ = -3.155, p = .002, and the consistent local condition (M = .067, SD = .251), $t(74)$ = -3.158, p = .002. Further paired *t*-test showed that target sentence was substituted more in the inconsistent conditions (*M* = .2, *SD* = .296) than the consistent conditions (*M* = .0733, *SD* = .178), *t*(74) = -3.327, *p* = .001.

DISCUSSION

The purpose of this study was to examine the relationship between working memory and text coherence in Chinese text comprehension. From the results, there was a difference between low working memory span readers and high working memory span readers in time to detect inconsistency and accuracy of recall for Chinese passages with coherence breaks. In addition, there was an effect by consistency condition on both time to detect inconsistency and accuracy of recall.

Differences between Low-Span and High-Span Readers

In support of previous studies on working memory and text coherence (e.g., Daneman & Carpenter, 1980; Masson & Miller, 1983; Miyake, Just & Carpenter, 1994; Whitney, Ritchie, & Clark, 1991; Yang, Cui, & Chen, 1999), high-span readers took less times to detect passages with coherence breaks (*M* = 1.953 s, *SD* = .54) than low-span readers (*M* = 2.205 s, *SD* = .488), and they recalled more idea units (*M* = .451, *SD* = .167) than their low-span counterparts (*M* = .364, *SD* = .165). In addition, low-span readers distorted more target sentences (*M* = .0256, *SD* = .0768) than high-span readers (*M* = 0, *SD* = 0).

However, the reaction time results and recall findings do not support previous studies on text coherence. Albrecht and O'Brien (1993), and Hakala and O'Brien (1995) found that readers took longer to resolve the inconsistency by reprocessing earlier parts of the text, and thus had better memory for earlier text. In the present work, low-span readers did take longer to read the target sentences inconsistent with previous elaboration. But, instead of resolving the inconsistency by reprocessing earlier parts of the text, in the present study they distorted more target sentences than did high-span readers. Additionally, high-span readers did not take longer to read the target sentences inconsistent with previous elaboration. However, the recall results showed that they recalled more idea units than low-span readers, offering some evidence that they may have reprocessed earlier parts of text, and that such reprocessing had a positive effect on their memory.

Within the literature there is a disagreement about the significance of reaction times. Studies on working memory and text coherence consider reaction times as a measure of working memory capacity. That is, high-span readers take shorter to detect inconsistency, and low-span readers take longer to detect inconsistency. Studies on text coherence, however, consider reactions times as a measure of detecting inconsistency. Longer times imply a detection of inconsistency and possibly a better memory of the earlier parts of the text, whereas shorter times imply no detection of inconsistency and as such no reprocessing of earlier parts of the text. Both perspectives are able to explain their own results because studies on working memory do not typically measure accuracy to recall, and studies on text coherence do not typically measure readers' working memory capacities.

From the results of time to detect inconsistency and accuracy of recall, the present study considers reaction times as a measure of working memory capacities when working memory capacity is included in the analysis. High-span readers are found to take less time to detect inconsistency and to recall more idea units, whereas low-span readers are found to take longer to detect inconsistency and to recall less (but distort more). The present study does not favor considering reaction times as a measure of detecting inconsistency because low-span readers took longer, but yet did not recall more idea units, whereas high-span readers took less time and did recall more idea units.

The recall results further suggest that readers with different working memory capacities may adopt different comprehension strategies while reading passages with coherence breaks. To resolve inconsistency, high-span readers may reprocess earlier parts of the text to integrate with the target sentences, whereas low-span readers seem to distort the target sentence to make it consistent with the earlier text.

Presumably, the ability to suppress or deactivate irrelevant information may account for the different comprehension strategies adopted by low-span and high-span readers. Gernsbacher's (1991) structure building framework explains that less skilled readers have a less efficient mechanism to suppress irrelevant information. Similarly, Kintsch's (1998) construction-integration model explains that less skilled readers are less able to deactivate the contextually irrelevant items. Consistent with Gernsbacher and Kintsch, the present study found that low-span readers may have difficulties in suppressing irrelevant information from earlier parts of the text, so they revert to distorting the target sentence as a way to establish coherence. Alternatively, high-span readers appear to have the ability to deactivate irrelevant information from earlier parts of the text, so they can simply reprocess earlier parts of the text to establish coherence.

Times to Detect Inconsistency

Readers took longer to read the target sentence in the inconsistent conditions (*M* = 2.081 s, *SD* = .526) than in the consistent conditions (*M* = 1.941 s, *SD* = .55). Holding in abeyance the analysis of working memory capacity, such increased reading times could suggest that readers experienced comprehension difficulty and attempted to resolve inconsistency by different strategies. Such findings would support the constructionist hypothesis proposed by O'Brien and colleagues, as it suggests that readers may be checking for both local and global coherence in an attempt to construct a single coherent representation around the main protagonist (Albrecht & O'Brien, 1993; Hakala & O'Brien, 1995; O'Brien & Albrecht, 1992). When new information is inconsistent with the established representation, comprehension difficulties would occur and strategies to reestablish coherence are needed. Chinese readers, like their English counterparts, took longer to detect inconsistency in passages with coherence breaks. It appears that Chinese readers routinely checked for, and maintained, coherence at both a local and global level. That is, they were able to detect inconsistency and attempted to maintain global coherence.

Not surprisingly then, the results run counter to the minimalist hypothesis proposed by

McKoon and Ratcliff (1992). Under the minimalist hypothesis, readers should engage in inferential or elaborative processes only when attempting to maintain local coherence or when the information necessary to draw the inference or elaboration is readily available. As long as a text makes sense in the context of the immediately preceding sentences and does not require contact with earlier parts of a text, readers need not draw an inference. The target sentences in the present study could always be integrated with the immediately preceding sentences. As such, according to the minimalist hypothesis, the target sentences should not have been any more difficult to comprehend in the inconsistent conditions than they were in consistent conditions.

Accuracy of Recall

Chinese readers recalled more distortion units in the inconsistent conditions (*M* = .0097, *SD* = .0247) than in the consistent conditions (*M* = .0003, *SD* = .0023). They also introduced more substitution units in the inconsistent conditions (*M* = .052, *SD* = .07) than in the consistent conditions (*M* = .026, *SD* = .0512). Because the inconsistency centered on the elaboration and the target sentence, the resolving strategies should have occurred primarily for those two passage regions. As the recall confirmed, the elaboration region was distorted more in the inconsistent conditions (*M* = .0189, *SD* = .0446) than consistent conditions (*M* = .0013, *SD* = .0116), and the target sentence was also distorted more in the inconsistent conditions (*M* = .0267, *SD* = .1131) than consistent conditions (*M* = 0, *SD* = 0). In addition, the target sentence was substituted more in the inconsistent conditions (*M* = .2, *SD* = .296) than consistent conditions (*M* = .0733, *SD* = .178).

When Chinese readers detected inconsistency, they may have imagined that they had missed certain parts of the text or mixed up the subject of previous elaboration with the other character. Indeed, subjects spontaneously provided such explanations after the experiment was concluded. The strategies they used to establish coherence were designed to distort the earlier parts of the text and the target sentence or to substitute the subject of the target sentence with the other character. For example, even though readers remembered that Chi Kuen (Chinese translation for Ken) was a small man, they distorted that "even though Chi Kuen is small, he would like to keep in shape." Instead of writing that Chi Kuen enrolled in the boxing class, readers substituted that "Iao Ming (Chinese translation for Mike) enrolled in the boxing class."

A more detailed analysis of the recall patterns reveals that the resolution of these coherence breaks and their impact on memory depended on whether the coherence break occurred at a local or global level. When global coherence was violated, readers distorted more (*M* = .0185, *SD* = .0108). When local coherence was violated, readers both distorted (*M* = .0143, *SD* = .0087) and substituted more (*M* = .0064, *SD* = .101). In addition, readers distorted more at the elaboration region when global coherence was violated (*M* = .0267, *SD* = .0777). Readers also substituted more at the target sentence (*M* = .253, *SD* = .438) when local coherence was violated.

Chinese readers distort at local and global coherence breaks but substitute more at local coherence breaks. These results concur with the findings of Hakala and O'Brien (1995) that local coherence breaks elicited more distortion units. Substitutions are found to be another comprehension strategy readers adopt to establish coherence. All information that needs to be checked is currently active in working memory at local coherence break. With the name of the other character in mind, substituting the subject of the target sentence with the other character is an efficient strategy for reestablishing coherence. It is not surprising to find that the elaboration region was more distorted and the target sentence was substituted more. Since the inconsistency involved the elaboration region and the target sentence, any strategies to establish coherence should involve these two regions.

The coherence breaks did not facilitate the recall of more idea units as seen in previous studies (e.g., Albrecht & O'Brien, 1993; Hakala & O'Brien, 1995; Myers, Shinjo & Duffy, 1987; O'Brien & Myers, 1985). No difference was found between the idea units recalled in passages with and without coherence breaks. In addition, the elaboration region and the target sentence were not better recalled with coherence breaks than without coherence breaks.

Summary and Significance

The present study showed that there was a difference between low working memory span readers and high working memory span readers in both time to detect inconsistency and accuracy of recall in Chinese passages with coherence breaks. In addition, there was an effect on both time to detect inconsistency and accuracy of recall.

For the literature on Chinese text coherence, this study shows that Chinese readers, like their English counterparts, took longer to detect inconsistency in Chinese passages with coherence breaks. It appears that they routinely checked for, and maintained, coherence at local and global levels. That is, they were able to detect inconsistency and attempted to maintain global coherence.

In addition, when Chinese readers detected inconsistency, they seemingly reasoned that they had missed certain parts of the text or mixed up the subject of previous elaboration with the other character. The strategies they used to establish coherence were designed to distort the earlier parts of the text and the target sentence or to substitute the subject of the target sentence with the other character. However, the coherence breaks did not facilitate their recall of more idea units.

Chinese readers distorted more at local and global coherence breaks and substituted more at local coherence breaks. In addition, they distorted more at the elaboration region, when global coherence was violated, and substituted more at the target sentence, when local coherence was violated. All of these results are additions to the literature on Chinese readers.

For the wider literature on text coherence, the present study shows that substituting the subject of the target sentence with the other character is found to be another comprehension strategy readers adopt to establish coherence. Like distortion units, readers substituted more at the target sentence in the inconsistent conditions than in the consistent conditions. Readers also substituted more at local coherence breaks. This was the first study to examine substitution effects.

For the literature on working memory and text coherence, this study shows that high-span readers took less time to detect passages with coherence breaks and recalled more idea units than their low-span counterparts. Low-span readers took longer to detect passages with coherence breaks and distorted more than high-span readers. To resolve inconsistency, high-span readers appear to reprocess earlier parts of text to integrate the target sentences, and the reprocessing has subsequent memory benefit for the elaboration region. To resolve inconsistency, low-span readers distort the target sentence to make it consistent with the earlier parts of the text, and the distortion did not have any memory benefit for the elaboration region. These findings add to a large body of data on working memory and text coherence.

Limitation and Implications

To present the working memory span task, previous research was administered with computer software, such as E-prime (e.g., Kane et.al., 2004), or Micro Experimental Laboratory (e.g., Engle, Cantor & Carullo, 1992). However, with a limitation on the availability of such resources, this study used Microsoft PowerPoint and the Digitest-1000. Since the Digitest-1000 has been widely used for obtaining reaction times in sports science and medicine (e.g., Abrantes, Macas, & Sampaio, 2004), it stands as a reliable substitute to the software solution more commonly employed in psychology (e.g., Albrecht & O'Brien, 1993; Hakala & O'Brien, 1995; Long & Chong, 2001). Importantly, as this study was not interested in the accuracy to the millisecond for reading the target sentence, this limitation should have no effect on the results.

In closing, if researchers are able to come to understand how readers adapt to both the type of text being read and to their own information-processing limitations, they be able to better target instructional programs that shift the reader from maladaptive to adaptive strategies. By further exploring the conditions under which readers select different strategies and the factors that influence those strategies, researchers may be able to predict more precisely the conditions under which coherence breaks improve and disrupt both memory and learning.

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APPENDIX A: OPERATIONS POOL

(9 × 1) – 9 = 1	(3 ÷ 3) + 1 = 2	(4 ÷ 1) - 1 = 5
(8 × 1) + 8 = 16	(8 ÷ 4) - 2 = 2	(7 × 1) – 6 = 2
(7 × 1) + 6 = 13	(2 ÷ 1) - 2 = 2	(8 × 1) + 5 = 13
(10 × 2) + 3 = 23	(6 ÷ 2) + 1 = 4	(4 ÷ 2) - 1 = 3
(9 × 7) – 1 = 49	(7 × 7) + 1 = 50	(4 ÷ 2) - 2 = 2
(6 ÷ 2) – 3 = 2	(5 ÷ 1) - 1 = 6	(8 ÷ 2) - 4 = 2
(7 × 7) – 1 = 49	(10 × 2) + 3 = 23	(6 × 3) – 2 = 17
(8 ÷ 1) – 5 = 5	(3 ÷ 1) - 1 = 4	(6 ÷ 3) + 2 = 4
(10 ÷ 1) – 9 = 3	(4 × 2) – 2 = 7	(10 ÷ 1) + 9 = 19
(10 × 6) + 1 = 61	(3 ÷ 1) + 3 = 6	(9 ÷ 1) + 8 = 18
(8 × 4) + 2 = 34	(9 × 2) – 1 = 18	(4 × 2) + 1 = 9
(10 × 5) + 2 = 52	(4 × 4) + 1 = 17	(10 ÷ 2) + 4 = 9
(10 ÷ 2) + 6 = 10	(3 ÷ 1) - 2 = 3	(4 ÷ 2) - 1 = 3
(9 ÷ 1) + 1 = 10	(6 × 1) – 6 = 1	(5 ÷ 1) + 4 = 9
(6 × 4) + 1 = 25	(5 ÷ 5) + 1 = 2	(8 ÷ 4) + 2 = 4
(3 × 1) – 2 = 2	(4 ÷ 1) - 4 = 2	(7 × 2) + 3 = 17
(6 ÷ 2) + 1 = 4	(6 × 2) + 2 = 14	(9 ÷ 3) + 1 = 4
(10 ÷ 1) + 3 = 13	(3 × 2) – 1 = 6	(9 ÷ 1) + 8 = 18
(7 ÷ 1) + 6 = 12	(2 × 1) + 1 = 3	(4 × 2) + 1 = 9
(10 ÷ 2) + 4 = 9	(10 ÷ 1) - 5 = 7	(10 ÷ 2) + 4 = 9
(8 × 2) – 4 = 13	(5 × 1) + 1 = 6	(4 ÷ 2) - 1 = 3
(7 ÷ 1) – 2 = 7	(9 × 3) + 2 = 29	(5 ÷ 1) + 4 = 9
(10 ÷ 2) – 4 = 3	(10 ÷ 2) - 4 = 3	(6 × 4) + 1 = 25
(10 ÷ 1) + 1 = 11	(9 ÷ 3) + 3 = 6	(3 ÷ 1) + 1 = 4
(10 ÷ 1) + 3 = 13	(8 ÷ 1) - 6 = 4	(3 × 2) – 1 = 6
(10 ÷ 1) + 9 = 19	(7 × 2) – 1 = 14	
(2 ÷ 2) + 2 = 2	(9 ÷ 1) - 7 = 4	
(10 ÷ 1) - 1 = 11	(9 ÷ 1) + 5 = 14	

APPENDIX B: CHINESE CHARACTERS POOL

同 因 好 她 如 成 此 自 至 行 但 作 你 更 沒 見 那 事 些 兩 其 和 定 性 或

所 於 明 法 知 者 表 長 便 前 度 很 後 政 看 美 重 面 香 員 家 能 起 高 動

問 將 從 情 理 現 都 最 場 就 港 無 然 發 著 開 間 意 想 新 當 經 道 實 對

種 與 麼 樣 學 機

APPENDIX C: READING TASKS POOL

(1)

Introduction: Ken and his friend Mike had been looking for summer activities for quite some time. They were both school teachers and they had the summers off from teaching. This meant that they both had plenty of time to try new things.

Consistent elaboration: Ken was a big man and always tried to keep in shape by jogging and lifting weights. His 250 pound body was solid muscle. Ken loved tough physical contact sports which allowed him to match his strength against another person.

Inconsistent elaboration: Ken was a small man and didn’t worry about staying in shape. His 120 pound body was all skin and bones. Ken hated contact sports, but enjoyed non-contact sports, such as Tai-chi and Yoga which he could practice alone.

Global coherence filler: While walking downtown during their lunch break one day, Ken and Mike passed a new Community Center. They noticed the display in the window. It was an advertisement for the Center’s summer sports program. They started looking at the advertisement and were impressed with the long list of activities that the Center sponsored. As they continued to look over the list, they became very excited. It seemed interesting so Ken and Mike went inside.

Local coherence filler: While walking by a new Community Center, they saw a flyer for the Center’s summer sports program.

Target sentence: Ken decided to enroll in boxing classes.

Close: He felt this would be the perfect activity. Ken signed-up for the class and paid the registration fees. He couldn't wait for the class to begin. When he was finished, they exited the Center and continued their walk downtown.

Question: Was Ken looking for an activity?

(2)

Introduction: Bill had always enjoyed walking in the early morning and this morning was no exception. During his walks, he would meet his neighbor Dave and they would walk together.

Consistent elaboration: Bill had just celebrated his twenty-fifth birthday. He felt he was in top condition and he worked hard to maintain it. In fact, he began doing additional workouts before and after his walks. Bill could now complete a five kilometers run with hardly any effort.

Inconsistent elaboration: Bill had just celebrated his eighty-first birthday. He didn’t feel as strong as he was twenty years ago. In fact, he began using a cane as he hobbled along on his morning walks. Bill could not walk around the block without taking numerous breaks.

Global coherence filler: Bill and Dave had been friends for quite some time. While walking today they were talking about how hot it had been. For the past three months there had been record breaking high temperatures and no rain. Soon there would be mandatory water rationing. As Bill was talking to Dave, he saw a young boy who was lying in the street hurt.

Local coherence filler: As Bill and Dave were walking one morning, they saw a young boy who was lying in the street hurt.

Target sentence: Bill quickly ran and picked the boy up.

Close: He carried him to the side of the road. While he helped the boy, Dave used his cell phone to call the boy's mother and an ambulance. Bill kept the boy calm and still until help arrived.

Question: Did Bill hate walking in the morning?

(3)

Introduction: Today, Mary was meeting her friend Joan for lunch. She arrived early at the restaurant and decided to get a table. After she sat down, she started looking at the menu.

Consistent elaboration: This was Mary's favorite restaurant because it had fantastic hot food. Mary enjoyed eating anything that was made from chili and curry. In fact, she ate at Sichuan restaurant at least three times a week. Mary never worried about her diet and saw no reason to eat plain foods.

Inconsistent elaboration: This was Mary's favorite restaurant because it had fantastic health food. Mary, a health nut, had been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease.

Global coherence filler: After about ten minutes, Joan arrived. It had been a few months since they had seen each other. Because of this Mary and Joan had a lot to talk about and chatted for over a half hour. Finally, they signaled the waiter to come take their orders. They checked their menus one more time. Mary and Joan had a hard time deciding what to have for lunch.

Local coherence filler: After Joan arrived, the waiter took their orders.

Target sentence: Mary ordered a fried spicy chicken.

Close: She handed the menu back to the waiter. Joan decided to try something new. She ordered and they began to chat again. They didn't realize there was so much for them to catch up on.

Question: Was Mary meeting her husband for lunch?

(4)

Introduction: Mrs. Dolan's daughter, Kim, had just started kindergarten. She was happy that Kim had made a lot of friends. Kim would often tell her mom about her friend Amanda at school.

Consistent elaboration: Lately, all Kim talked about was how much she loved animals. Little Kim loved animals so much she refused to leave a room that had any type of pet in it. Every time she saw an animal she wanted to pet it and take it home. Mrs. Dolan didn't know why Kim loved animals so much.

Inconsistent elaboration: Lately, all Kim talked about was how much she hated animals and how frightened she was of them. In fact, she refused to go in the same room with a cat. Every time an animal approached her, she ran away and began to cry. Mrs. Dolan didn’t know why Kim was so frightened of animals.

Global coherence filler: Mrs. Dolan always dropped Kim off at school. Today, however, Kim wanted her mom to come into the school with her. She wanted her mom to see her art work and meet her friend, Amanda. When they arrived, Kim was met at the school doors by Amanda. As the three entered the classroom, they looked around. Kim and Amanda noticed that someone had brought in their pet and all the children were gathered around it.

Local coherence filler: When Kim and Amanda arrived at school today, they noticed that someone had brought in their pet.

Target sentence: Kim ran across the room to pet the dog.

Close: She smiled as she brushed the dog's fur. Kim waved to her mom and asked her to come see the dog. Mrs. Dolan walked to the other side of the room and knelt down beside Kim and petted the dog.

Question: Was Mrs. Dolan’s daughter in high school?

APPENDIX D: CONSENT FORM

The purpose of this study is to understand how memory is related to reading. You are requested to spend 45 minutes to finish a memory task and a reading task presented in Microsoft PowerPoint. There will be a practice before both tasks so that you understand how to finish them before proceeding. If you have any questions, please feel free to ask at any time (now or throughout the experiment). During the memory task, you will verify quickly and accurately the accuracy of a series of mathematical operations, and memorize a Chinese character. During the reading task, you will read four passages at a normal and comfortable pace. You are asked to press the “enter” on the keyboard with one hand and the “start” button on the Digitest-1000, a meter to count your reading time, with your other hand simultaneously.

The risks are expected to be no greater than those normally encountered in completion of daily instructional activities. Meanwhile, there are no direct benefits to your participation. Your participation in this study is completely voluntary. There is no penalty for not participating, and you may leave this study at any time for any reason.

All of your records will be given a number instead of your name. You will be given a copy of this consent form to keep, but the original signed copy will be kept separately from the data, so that your name will never be associated with any of the results of the study. All records in this study will be locked in a cabinet and only the researcher has access to them.

Should you have any questions or concerns regarding this research, please feel free to contact the researcher, Ms. Sau Hou Magdalen Chang, a lecturer at the Faculty of Education at the University of Macao, at Rm. 203, Tai Fung Building, telephone 6618933 or 3974203, e-mail shchang@umac.mo, or her academic advisor, Dr. Tracy Henley, Head of the Department of Psychology and Special Education at Texas A & M University-Commerce, at Rm. 201 Henderson Hall, telephone 903-886-5200, and e-mail

Tracy_Henley@TAMU-Commerce.edu. Should you have any questions or concerns about the appropriate conduct of the research or your rights as a subject, please feel free to contact the chairperson of the Institutional Review Board, Dr. Tracy Henley through the above means.

Thank you for generously donating your time to this psychological study which is part of the requirement of the researcher to complete a graduate program at the Department of Psychology and Special Education at Texas A & M University– Commerce, USA.

“The purpose and procedures of this study has been clearly explained. It is understood that participation is completely voluntary and can be withdrawn at any time for any reason. It is also assured that the confidentiality of records is protected. Therefore, a voluntary participation in this study is granted to the researcher by the signed party.”

Name of participant: ____________________________ Date: _____________

APPENDIX E: INSTRUCTIONS

You are going to take about 45 minutes to complete two tasks: the operation-character task and the reading task. All these are presented in Microsoft PowerPoint via the IBM ThinkPad. Please adjust your position so that you can read the computer screen and press the "enter" on the keyboard easily and comfortably.

At the beginning of the operation-character task, a "+" sign will be presented at the center of the computer screen for 1 second, followed by a blank screen for another 1 second. Then, a mathematical operation will appear and you have to mentally calculate it immediately and press the "enter" key on the keyboard to verify whether the answer given on the next screen was correct by saying out "True" or "False." You have to perform the operation verification as quickly as possible, but to be accurate.

After the verification, please press "enter" and memorize the Chinese character shown on the next screen for 1 second. Then, the screen will be blank for 1 second, followed by either another operation-character pair or the recall cue (a set of 3 question marks) at the center of the screen. The question marks signal you to write down in the correct order the Chinese characters you have memorized. You are refrained from writing down the last character first. Guessing is encouraged, and recall is not timed. After writing the characters, you could press the "enter" to proceed to the next screen starting again with a "+" sign. There are 18 times you will be asked to write down the Chinese characters you have remembered, but you will not know how many characters you have to write at each time.

At the beginning of the reading task, a "+" sign followed by a number of "~" characters was presented for 1 second and this was followed by a blank screen for another 1 second. The passages were presented one line at a time on the computer screen, and each subsequent press of "enter" erases the current line and presents the next one. A meter is placed next to the keyboard and you have to press the "start" button on the meter with your dominant hand while simultaneously pressing the "enter" on the keyboard with the other one. At the end of each passage, a closed-end question is presented, and you have to tell the answer verbally by saying "Yes" or "No." Although the meter counts the reading times, this is not a speed test. There are four passages for you to read at a normal and comfortable pace.

There will be a practice before both tasks so that you understand how to finish them before proceeding. If you have any questions, please feel free to ask at any time (now or throughout the experiment).