The 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 participants completed an operation-character working memory span task to be classified into low-span and high-span readers and a reading task to measure the time to detect inconsistency as well as the 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 studies.

Keywords: working memory, text coherence, Chinese text comprehension

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The Role of Working Memory and Text Coherence in Chinese Text Comprehension

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 comprehension. In addition to understanding words and grammar, comprehension is the creation of a coherent mental representation of a text. 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). According to the minimalist hypothesis, readers are primarily concerned with maintaining local coherence and they establish global coherence only when local coherence fails (McKoon & Ratcliff, 1992) In contrast, the constructionist hypothesis asserts that readers routinely check and maintain coherence at both a local and global level (O'Brien & Albrecht, 1992; Albrecht & O'Brien, 1993; Hakala & O'Brien, 1995).

There is also the idea, noted by Daneman and Carpenter (1980), that readers with larger working memory spans would be better at text comprehension. Miyake, Just, and Carpenter (1994) reported that both high-span and low-span readers activated multiple meanings of an ambiguous word, but only high-span readers were able to suppress irrelevant ones. Similar results were previously obtained by Daneman and Carpenter (1983), who found that readers with smaller spans detected ambiguous words about as often as readers with larger spans; however, they did not comprehend as well as readers with larger spans. Likewise, Whitney, Ritchie, and Clark (1991) suggested that low-span readers faced a tradeoff between maintaining global coherence and maintaining local coherence.

The majority of this work has been with the English language. However, Siu (1986) posited that Chinese text coherence was similar. In addition, Chow, Chan, Song, and Chen (2000) showed an effect for the time to read inconsistent Chinese phrases and Wang and Mo (2001) noted that Chinese readers took longer with inconsistent sentences than consistent ones. Yang, Cui, and Chen (1999) additionally found that readers with high working memory capacities took less time to verify the meaning of ambiguous Chinese sentences than readers with lower working memory capacities.

In addition, previous studies on Chinese text coherence (e.g., Chow, Chang, Song, & Chen, 2000; Wang & Mo, 2001) have used target sentences that were either consistent or inconsistent with relevant preceding elaborations to investigate the effect of consistency on reaction times. The present study uses that same paradigm to investigate the effect of consistency on reaction times, but also considers recall accuracy. We expect to see results consistent with similar English language studies (e.g., Hakala & O'Brien, 1995).

Unlike previous studies using passages with one protagonist, the present study used passages with two protagonists. This is an addition to the literature that should increase ecological validity, given that many "real world" texts include multiple protagonists. As such, an analysis of the number of "substitutions" was added to the standard methods for scoring distortions (e.g., recall errors; Hakala & O'Brien, 1995). A response was scored as a substitution if the subject of the action was substituted with another protagonist. As is the case with distortions, readers are expected to have more substitution units from passages with inconsistent local conditions than with inconsistent global conditions.

Last, although working memory capacity has been related to text coherence at both local and global levels (e.g., Kintsch & van Dijk, 1978), studies on working memory and text coherence have mostly focused on reaction times (Daneman & Carpenter, 1980; Miyake, Just, & Carpenter; 1994; Whitney, Ritchie, & Clark, 1991). In the present study, Chinese readers with different working memory capacities were also scored for recall of passages with inconsistencies at global and local levels. Although some work speaks to this point (e.g., Yang, Cui, & Chen, 1999; Wang & Mo, 2001), no previous study has used methods fully suited to address this question.

The purpose of this study then is to further examine the relationship between working memory and text coherence in Chinese text comprehension. Specifically, based on the English language literature, 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 as well as in the accuracy of recall.

Method

Participants

Participants were 86 undergraduate education majors enrolled in psychology courses at University of Macau. There were 76 females and 10 males, aged 18 to 22. All were native Cantonese speakers, and all instructions were in Cantonese.

Design

The present study was a 2 working memory (low-span or high-span) × 2 consistency (consistent or inconsistent) × 2 coherence (local or global) analysis of variance on target-sentence reading times, as well as on the percentage of correct idea units, distortions, and substitutions recalled by participants.

Materials

Operation-character span task.

This study adopted the operation-word paradigm developed by Engle and colleagues for measuring working memory capacities (e.g., La Pointe & Engle, 1990). Since the participants were Chinese, the operation-word span was changed to an operation-character span. The operation-character task consisted of a series of paired mathematical operations and Chinese characters. The mathematical operations came from La Pointe and Engle, and the Chinese characters came from a database of Chinese character frequencies (Humanities Computing and Methodology Program, & Research Institute for the Humanities, 2002). 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). Examples of the stimuli included: (9 × 1) – 9 = 1 同; (8 × 1) + 8 = 16 因.

Reading task.

Four reading passages developed by Long and Chong (2001) were rewritten into Chinese. Contents were modified to address cultural differences between Americans and Chinese. For example, Chinese usually do not order a cheeseburger and fries, so the Chinese version described ordering a spicy fried chicken. Initial translations were made by the first author, then reviewed by a Professor of Bilingual Translation (in Macau) who checked both versions to verify that the Chinese corresponded with the English with respect to matters such as length, complexity, and consistency.

Each passage had five regions: introduction, elaboration, filler, target sentence, and close. Each passage began with a two- to three-sentence section introducing two protagonists. This was followed by an elaboration sentence that would be either consistent or inconsistent with the subsequent target sentence. A paraphrased consistent example would be: Mary loved hot food (elaboration) and ordered a spicy chicken (target). An inconsistent example would be: Mary was a vegetarian (elaboration) but ordered a spicy chicken (target). One of two possible filler sections followed to strain working memory. For the global coherence conditions, approximately six sentences were used, and for the local coherence condition only one sentence was used. The filler region was followed by the target sentence (which was either consistent or inconsistent with the previous elaboration), and then the story closed.

Procedures

Two computer-based tasks, averaging 45 minutes total, were presented individually to subjects in a counterbalanced manner.

Operation-character span task.

The mathematical operation and Chinese characters were presented in black against white in 44-point font as follows. At the beginning of a trial, a "+" sign was presented at the center of the screen for 1 second, followed by a blank screen for 1 second. Then, a mathematical operation appeared, and participants were instructed to mentally calculate (e.g., [(6 × 2) – 5 = ?]). When participants had their answer, they pressed "enter" to proceed to the next screen. An answer for the operation would then be given on screen, and participants verified whether it was correct by indicating "True" or "False." Participants were instructed to perform the verification as quickly as possible, but to be accurate. Then, they pressed "enter" to move onto the next screen that showed a Chinese character for 1 second and were to memorize it for later recall. The screen was blank for 1 second, followed by either another operation-character pair or the recall cue (a set of question marks). The cue signaled participants to write down, in the correct order, the preceding Chinese characters. Participants were asked to refrain from writing down the last character first. Recall was not timed. When participants finished writing they pressed "enter" to proceed to the next 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). Time to read the target sentence and the response to a comprehension question for each passage were recorded. Each of the four text passages was presented in four formats: global consistent, global inconsistent, local consistent, local inconsistent, resulting in 16 counterbalanced conditions.

The reading time of the target sentence was measured by the Digitest-1000, an instrument used to record reaction time in milliseconds in sports and medicine. Participants activated the Digitest-1000 with their dominant hand while simultaneously pressing “enter” on the keyboard. Each subsequent press of “enter” erased the current line of the passage and presented the next one. At the beginning of a trial, a “+” sign followed by several “~” characters was presented on the screen for 1 second, followed by a blank screen for 1 second. The passages were presented one line at a time in black against white in 44-point font. At the end of each passage, a close-ended question was presented as a fidelity check to assure that participants were attending and understanding.

After all four texts were read on the screen, participants were given a test booklet to write down all they could remember about each passage. Each page of the booklet provided a recall cue (the first sentence) for a particular passage in the same order that they were read. Recall was scored consistent with established methods (Hakala & O’Brien, 1995).

Results

Working Memory Task

The 86 participants’ span scores were screened by stem & leaf plot. Data that were more than 1.5 times the interquartile range from the upper or lower quartile were considered outliers, and three low span scores were thus excluded from further analyses. Cronbach’s alpha (.77) was derived from the proportion-correct scores of the six operation-characters pairs, and suggested internal consistency was acceptable.

Operation-character span scores (*M* = .801, *SD* = .116) ranged from .489 to .982. The median score (.824) was used as a cutting point between high-span and low-span readers. Participants with working memory scores equal to or below the median 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 (*M* = .714, *SD* = .095) and high-span readers (*M* = .891, *SD* = .045), $t(81) = -10.807$, $p < .001$.

Reading Task

Reading task recall data in which participants produced no results for a passage were considered missing data. With 8 missing data and 3 span scores outliers, the analysis of the fidelity check questions was conducted on 75 participants. The percentage of correct answers was above 96% for each group, and there was no difference between the low-span and high-span readers in answering these questions.

Reaction times.

Latencies of all 86 reaction times were screened as previously described. Twelve outliers were found; including the 3 outliers from the span scores, 15 participants were now excluded, so 71 participants were used.

For the reaction times (Table 1), ANOVAs showed that there were main effects of passage condition, $F(3, 207) = 2.797$, $p = .041$, and working memory span, $F(1, 69) = 5.081$, $p = .027$, but no interaction between passage condition and working memory, $F(3, 207) = .91$, $p = .437$. Bonferroni's procedure showed that the times taken to read the target sentence in the inconsistent local condition were longer than those in the consistent local condition and showed that low-span readers took longer to read the target sentence than high-span readers in the consistent global condition and the inconsistent local condition.

Recall.

With 8 missing data and 3 span-scores outliers, 11 participants were excluded and 75 participants were used. For the idea units correctly recalled (Table 2), ANOVAs showed that there was a main effect for working memory, $F(1, 73) = 4.173$, $p = .045$. but not for passage condition, $F(3, 219) = .702$, $p = .552$, nor any interaction between passage condition and working memory, $F(3, 219) = .993$, $p = .397$. Post hoc analysis showed that high-span readers correctly recalled more idea units than low-span readers in the inconsistent global condition.

Considering idea units across different passage regions (Table 3), ANOVAs showed that there were main effects for the passage regions, $F(3.326, 242.779) = 81.787$, $p < .001$, and for working memory, $F(1, 73) = 4.173$, $p = .045$, but no interaction between passage region and working memory, $F(3.326, 242.779) = .204$, $p = .91$. Post hoc analysis showed that high-span readers recalled more idea units than low-span readers in the elaboration region.

For the distortions (recall errors) produced (Table 2), ANOVAs showed that there was a main effect for passage condition, $F(1.803, 131.613) = 3.227$, $p = .048$, but not for working memory, $F(1, 73) = 1.872$, $p = .175$, nor any interaction effect between passage condition and working memory, $F(1.803, 131.61) = .999$, $p = .364$. Paired *t*-tests showed that readers provided more distortions in the inconsistent global condition than in the consistent global condition, $t(74) = -2.465$, $p = .016$, and consistent local condition, $t(74) = -2.628$, $p = .01$. Participants also provided more distortions in the inconsistent local condition than in the consistent local condition, $t(74) = -2.022$, $p = .047$.

Looking at distortions across passage regions (Table 3), ANOVAs showed that there were main effects for region, $F(3, 71) = 6.559$, $p = .001$, but no main effect for working memory, $F(1, 73) = 1.872$, $p = .175$, nor any interaction between passage region and working memory, $F(3, 71) = 1.82$, $p = .151$. Independent *t*-tests showed that low-span readers produced more distortions at the target region than high-span readers, $t(73) = 2.001$, $p = .049$.

For substitution errors (Table 2), ANOVAs showed that there was a main effect for passage condition, $F(3, 219) = 4.082$, $p = .008$, but not for working memory, $F(1, 73) = .408$, $p = .525$, nor any interaction effect between passage condition and working memory, $F(3, 219) = 1.233$, $p = 2.99$. Bonferroni's procedure showed that readers produced more substitutions in the inconsistent local condition than in the consistent global and consistent local conditions.

As for substitutions across locations (Table 3), ANOVAs showed that there was a main effect for passage region, $F(1.376, 100.442) = 31.626$, $p < .001$, but not for working memory, $F(1, 73) = .408$, $p = .525$, nor an interaction between region and working memory, $F(1.376, 100.442) = .279$, $p = .673$. Bonferroni's procedure showed that readers produced more substitutions at the target sentence than any other region.

Discussion

The purpose of this study was to examine the relationship between working memory and coherence in Chinese text comprehension. Results suggest there was a difference between low (working memory) span readers and high-span readers in time to detect inconsistency, and in accuracy of recall for inconsistent passages.

Consistent with previous studies using Mandarin readers (Chow, Chan, Song, & Chen, 2000; Wang & Mo, 2001), Cantonese readers took longer to read the target sentence in the inconsistent conditions than in the consistent conditions. Specifically, participants took longer to read the target sentence in the local inconsistent condition than in the local consistent condition. Such findings could support the minimalist hypothesis (e.g., McKoon & Ratcliff, 1992) that readers establish global coherence only at local inconsistencies. It also extends studies on Chinese text comprehension from simply investigating the effect of consistency on reaction time, to considering the effects on recall.

Previous studies using English texts with one protagonist found that correct recall increases in global inconsistent conditions and distortions increase at local inconsistent conditions (Hakala & O'Brien, 1995). The present study, using passages with two protagonists showed that readers had more distortions in the inconsistent conditions than in the consistent conditions. Additionally, readers made more erroneous substitutions in inconsistent conditions than in consistent conditions. With the name of the other protagonist in mind, substituting the subject of the target sentence with the other protagonist was likely a more efficient strategy than distorting the events in the elaboration region. As such, the present study adds to our knowledge on recall of inconsistent passages by using more ecologically valid materials given that multiple protagonists are commonplace in everyday discourse.

High-span readers were previously found to take shorter times than low-span readers to verify the meaning of ambiguous Chinese sentences (Yang, Cui, & Chen, 1999). The present study also found that high-span readers took shorter times than low-span readers to detect inconsistent target sentences, and high-span readers took less time than low-span readers to read the target sentence in the local inconsistent condition. Additionally, high-span readers correctly recalled more than low-span readers in the global inconsistent condition. Importantly, this extends findings on working memory and text coherence from just measuring reaction times to include recall.

High-span readers did not take longer than low-span readers to read target sentences inconsistent with previous elaboration, but they correctly recalled more than low-span readers in the elaboration region. This suggests that high-span readers may have reprocessed earlier parts of the text to confirm that there was an inconsistency, and such reprocessing had a positive effect on recall. Low-span readers took longer than high-span readers to read target sentences inconsistent with previous elaboration, but they provided more distortions at the target region than high-span readers. This suggests that low-span readers may have detected an inconsistency, but their limited working memory capacities may not afford reprocessing of earlier text. Instead, they distort the target sentence. As text reading temporally unfolds, high-span readers seem to be able to integrate the accumulated information whereas low-span readers seem to utilize only recent information in understanding the text.

Such findings are different from previous studies where readers took longer to resolve the inconsistency and had better memory for earlier text (e.g., Albrecht & O'Brien, 1993; Hakala & O'Brien, 1995). One possible explanation of such deviation between high-span and low-span readers may come from the ability to suppress irrelevant information. Gernsbacher's (1991) structure-building framework argues that less skilled readers have an inefficient mechanism to suppress irrelevant information. Similarly, Kintsch's (1998) construction-integration model posits that less skilled readers have difficulty deactivating contextually irrelevant items. Consistent with Gernsbacher and Kintsch, the present study found that low-span readers provided more distortions than high-span readers. Low-span readers may have difficulties in suppressing irrelevant information from earlier parts of the text, so they took more time but still distorted more. On the other hand, high-span readers seemingly have the ability to deactivate irrelevant information from earlier parts of the text, so they take less time and recall more accurately.

In sum, the present study contributes to our knowledge of Chinese text comprehension and juxtaposes results from Chinese participants with those from English speakers. Moreover, it extends the literature on working memory and comprehension from just reaction times to include recall of the passages, and introduced the use of substitution units as another measure of error. In closing, although similarity between Chinese text comprehension and English text comprehension implies a universal processing mechanism across different language systems, further studies are needed to illuminate such mechanisms.

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Table 1

Mean Reading Times (in Seconds) for Target Sentence as a Function of Passage Condition 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

Table 2

Mean Percentage of Idea, Distortion, and Substitution Units Produced as a Function of Passage Condition and Working Memory Span

		Idea Units					Distortion Units					Substitution Units				
		Consistent		Inconsistent			Consistent		Inconsistent			Consistent		Inconsistent		
Working Memory		Global	Local	Global	Local	Total	Global	Local	Global	Local	Total	Global	Local	Global	Local	Total
Low-span	*M*	.414	.397	.364	.422	.399	0	0	.0128	.0145	.007	.023	.025	.058	.063	.042
n=39	*SD*	.156	.196	.165	.172	.172	0	0	.0456	.0495	.0238	.063	.084	.094	.095	.085
High-span	*M*	.435	.475	.451	.454	.454	.0011	0	.0083	.0024	.003	.031	.024	.021	.066	.035
n=36	*SD*	.138	.185	.167	.176	.167	.0067	0	.0185	.0143	.0099	.074	.06	.058	.011	.051
Total	*M*	.424	.434	.406	.437	.425	.0005	0	.0107	.0087	.005	.027	.024	.04	.064	.039
N=75	*SD*	.147	.194	.171	.174	.172	.0046	0	.0352	.0373	.0193	.068	.073	.08	.101	.081

Table 3

Mean Percentage of Recall as a Function of Passage Region and Working Memory Span

	Idea Units						Distortion Units						Substitution Units					
Working Memory	Intro	Ela	Filler	Target	Close	Total	Intro	Ela	Filler	Target	Close	Total	Intro	Ela	Filler	Target	Close	Total
Low-span (*n*=39)	.402	.331	.441	.628	.193	.399	0	.0085	0	.0256	0	.0068	.011	.023	.003	.147	.026	.042
High-span (*n*=36)	.468	.392	.495	.694	.22	.454	.003	.0118	0	0	0	.003	.007	.029	0	.125	.017	.035
Total *(N=75)*	.434	.361	.467	.66	.206	.425	.0015	.0102	0	.0128	0	.0049	.009	.026	.002	.137	.022	.04