第二言語読解における長期ワーキングメモリの役割
The Role of Long-Term Working Memory in Second Language Comprehension

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Keywords

ABSTRACT

Long-term working memory (LT-WM) plays an important role in comprehension processes because the capacity-limited short-term working memory (ST-WM) alone cannot handle a large amount of information that has to be processed during comprehension. LT-WM is claimed to be a portion of long-term memory (LTM) that is not activated but can easily be activated by ST-WM elements as retrieval cues. It is also argued that LT-WM is restricted to well practiced and familiar knowledge domains. Reading for non-fluent second language (L2) learners is not such a domain. Does this imply mean that LT-WM does not play a role in L2 comprehension? The present study tested this question by contradiction detection experiments, following the study by Albrecht and O'Brien (1993). The results showed that Japanese learners of English could not detect an inconsistency in a text during reading when contradicting portions were separated only by a single sentence. This outcome suggests that the prior textual information is not retrieved during reading. The implications of these results concerning LT-WM are that the contradicting information is not in LT-WM, and that LT-WM does not seem to play the kind of role as it does in L1 comprehension.

　長期ワーキングメモリ（LT-WM）は読解過程に重要な役割を果たすと言われる。というのは，容量に制限のある短期ワーキングメモリだけでは，理解過程中に情報量の多い文章の処理がすべて行われると考えるには無理があるからである。LT-WMは，長期記憶（LTM）のうち活性化されていないが，ST-WMの情報を検索手がかりとして簡単に活性化できる部分と考えられている。また，LT-WMは熟達した領域に限られるともされている。第二言語（L2）学習者にとっては，読解は当然のとこながらそのような

領域ではない。では，LT-WMは，L2学習者には役に立たないものなのだろうか？本研究は，Albrechtと O'Brien（1993）に従い，不一致効果を利用した実験によってこの問いを検証した。その結果，日本人英語学習者は，相矛盾する文の間に1文が挿入されただけで不一致に気づかないことが示された。この結果は，読解中に矛盾を含む先行文を検索できない，すなわち，先行文がLT-WMにないことを示唆する。従って，L2ではLT-WMは，第一言語（L1）におけるような働きをしていないと思われる。

1. Introduction

Reading comprehension is a complex cognitive activity that involves a number of processes ranging from letter recognition, lexical identification, and propositional analysis to construction of a situation model. Working memory (WM) plays an important role in language comprehension. One of the developments in the understanding of WM is the theory of long-term working memory (LT-WM) (Ericsson and Kintsch, 1995). One of the motivations for the formulation of this memory is to account for reading comprehension. It is generally accepted that short-term working memory (ST-WM) operates under severe capacity constraints. A number of observations concerning on-line comprehension processes cannot be accounted for by the capacity-limited ST-WM. To explain such observations, the notion of LT-WM has been devised (e.g., Kintsch, 1998). LT-WM is claimed to be a portion of LTM that is not activated but can easily be activated by ST-WM elements as retrieval cues, and it is characterized by fast, automatic retrieval processes. Given the importance of LT-WM in native language (L1) comprehension, this notion has begun to gain attention from researchers in second language (L2) comprehension in recent years. A key and basic question concerning LT-WM in L2 comprehension is whether this memory plays a role in on-line processes in L2 reading. The present study addresses this question, and this article presents preliminary data to answer the question.

Before broaching into the main topic, let us briefly discuss major differences between L1 and L2 in text comprehension processes. On the one hand, in L1 comprehension, a great deal of language processes, especially low-level processes such as lexical access, parsing, and proposition formation procedures are considered to be automatic, and consume only a small amount of cognitive resources. On the other hand, L2 language processes are largely controlled, requiring a substantial amount of cognitive resources. Zwaan and Brown (1996) found that their participants constructed a more complete situation model when reading in L1 than in L2, and that when they were reading in L2, they concentrated on lower-level processes associated with the development of a surface form and textbase. Their findings can be accounted for by the notion of cognitive capacity (e.g., Just and Carpenter, 1992). A comprehender has a limited amount of processing resources available at any given time, and different cognitive processes for comprehension compete for this limited processing resources. When the demand for processing resources is greater than the supply, lower-level processes will be prioritized at the expense of higher-level processes. As stated above, L1 readers have automatized lower-level linguistic processes to a greater degree and are thus able to devote much of their resources to higher-level processes such as discourse comprehension, learning, and thinking (Harrington & Sawyer, 1992; Perfetti, 1985). In contrast, in L2 reading, a greater amount of cognitive resources are consumed by low-level processes, and consequently there is a relatively smaller amount of cognitive resources available for higher-level processes for discourse comprehension, and thus they may not be performed or, even if they

are, they may have to be performed with more effort.

LT-WM is claimed to be restricted to well practiced and familiar knowledge domains (Kintsch, Patel, & Ericsson, 1999). The proponents of the model (Kintsch et al., 1999) state that "the LT-WM theory claims that superior memory in expert domains is due to LT-WM, whereas in non-expert domains LT-WM can be of no help." In other words, if one is highly skillful in comprehension, one can construct a representation in which currently processed text elements, which reside in ST-WM, are appropriately elaborated by and integrated with information of prior text memory and of relevant general knowledge. While L1 comprehension falls well in this domain, L2 comprehension does not because L2 learners' proficiency is by definition still insufficient. As stated above, LT-WM is characterized by fast, automatic retrieval processes. The question that arises here concerning LT-WM in L2 comprehension is whether such automatic reactivation of an earlier portion of text memory occurs during reading. According to the capacity view described above, in L2 comprehension LT-WM may not function during reading presumably because of the lack of sufficient resources needed for the construction, insufficient proficiency in the language, or possibly the combination of both of them.

In order to test the question, the present study employed the inconsistency detection paradigm. In a series of studies, O'Brien and colleagues (e.g., Albrecht & O'Brien, 1993; Gerrig & O'Brien, 2005; Myers, O'Brien, Albreacht, & Mason, 1994; O'Brien & Albrecht, 1992; O'Brien, Rizzella, Albrecht, & Halleran, 1998; Rizzella & O'Brien, 1996) examined whether L1 readers maintain global coherence even when local coherence is maintained. Their experiments employed an inconsistency detection paradigm. Suppose that a currently processed sentence (e.g., "Mary ordered cheeseburger and fries.") contradicts with an earlier part of the text (e.g., Mary was a strict vegetarian."). If the text

memory is accessible on-line, then the reader would notice the inconsistency and try to resolve it. This would require more processing, and hence result in a longer reading time, compared to the case where there is no inconsistency (e.g. "Mary had was a fast-food addict."). For example, Albrecht and O'Brien showed that their participants indeed displayed longer reading times when the text contained an inconsistency than when it did not. Also, in another study (Myers et al., 1994) that employed the texts in which critical characteristics of a protagonist were backgrounded, the inconsistency effect was observed when the protagonist was reintroduced into the narrative in the context of carrying out an inconsistent action. The results of these studies provided support for the claim that the information from an earlier part of the text is accessed when the currently processed text element is encountered to maintain global coherence during comprehension.

Based on the research on L1 comprehension as described above, it is plausible to assume that L2 readers also try to access earlier portions of a text to maintain text coherence during reading. However, because of the limited resources that can be allocated to this kind of discourse processes, it is hypothesized that the extent to which the search of text memory reaches in memory would be more restricted than in L1 comprehension. Therefore, it is predicted that in comprehending a text that contains an inconsistency, L2 readers would not detect the inconsistency unless the distance between contradicting text elements is sufficiently short. To test this hypothesis, two experiments were conducted.

2. Experiment 1

In this experiment, the distance between contradicting parts was set to be one-sentence long. Compared to Albrecht and O'Brien's (1993) materials, in which the distances between contradicting parts were on average five- or six-

sentence long, the distance in this experiment was considerably short, namely only a single sentence. If it is indeed short enough for L2 learners, the inconsistency effect should occur.

2. 1. Method

Participants. Participants were 32 undergraduate students at International Christian University (ICU). They were all native speakers of Japanese and intermediate learners of English. They either had completed or were enrolled in the two-year intensive English Language Program, which was a requirement for all ICU students whose primary language was Japanese. All the participants had English language education in secondary schools in Japan and did not have extensive (i.e., longer than one year) overseas experiences. None of the participants were enrolled in the advanced level classes of the Program.

Materials. Twelve English passages were created, following Albrecht and O'Brien (1993). Each passage consisted of eight sentences. The first two sentences introduced the main protagonist. The next two sentences elaborated the story. The fifth sentence was a filler sentence that continued the story without making a reference to the protagonist or crucial information related to the inconsistency. The sixth sentence was designated as the target sentence. There were two post-target sentences that followed the target sentence. Each passage had the inconsistent and consistent versions. In the inconsistent version, the elaboration part was written in such a way that it contradicted with the target sentence. The consistent version did not contain such an inconsistency.

The twelve passages were divided into two sets. In the one set, the first six passages were assigned to the consistent condition and the other six to the inconsistent condition. In the other set, the passage assignment was reversed. Thus, text version (i.e., consistent vs. inconsistent) was a within-participant variable.

Procedure. Participants were randomly assigned to either text set. The participants were run individually and the experiment took approximately 20 minutes. The experiment was conducted on an Apple iBook computer with a 13-inch monitor. The computer screen was approximately 50 cm away from the eyes of the participant. The instructions to participants were given in Japanese. In each trial, the participants read a passage sentence by sentence at their own pace by pressing the pace bar to request a next sentence, and the sentence reading time was recorded by the computer. After reading the passage, there was a comprehension question to encourage them to attend to the text. Before the experimental trials, there were two practice trials.

2. 2. Results and Discussion

The number of incorrect answers of the comprehension questions was counted for each participant. The overall mean incorrect answers were 2.44 (SD = 1.41) out of 12 questions. None of the participant showed outstandingly poor performance, and thus the data from all participants were used for analysis. The mean number of incorrect answers for the consistent texts and that for the inconsistent texts were 1.38 (SD = .98) and 1.06 (SD = .98) respectively. This difference was not reliably significant, $t(31) = 1.31, p > .1$.

Mean reading times of the target sentences per text condition were calculated for each participant. Reading times greater than three standard deviations away from the overall conditional means were judged to be outliers and replaced by the threshold values. There were a total of 4 such observations, which comprised of 1.3% of all the data. Then the conditional means were calculated again for each participant.

Mean reading times of the post-target sentences were also calculated for each participant, applying the same outlier procedure for the target sentences. There were a total of 6 outliers, which comprised of

1.6% of all the observations.

Table 1 presents the mean reading times of the target sentence and the post-target sentence for the two conditions across participants. For the target sentence, the mean reading time was greater for the consistent condition than for the inconsistent condition. The statistical analysis with participants as a random factor showed that this difference was found to be marginally significant, $t(31) = 1.8$, $.05 < p < .1$. The analysis with items as a random factor did not show significance, $t(11) = 1.36$, $p > .2$. The post-target sentence did not differ significantly between the conditions by either analysis, $t(31) = .16$, $p > .8$ by participant analysis, and $t(11) = .75$, $p > .4$ by item analysis.

The data showed that a marginally significant difference in reading time for the target sentence was observed, but was in the opposite direction from that which was predicted by the inconsistency effect. One interpretation of this outcome is that the participants were not aware of or sensitive to the inconsistency in the text. Alternatively, the experiment failed to detect the effect. To examine this possibility, the same experiment was conducted with native speakers of English in Experiment 2.

3. Experiment 2

This experiment was conducted with native speakers of English to examine the appropriateness of the experimental design and materials. It was predicted that the contradiction effect with longer reading times for the contradictory texts should be observed. If the experiment replicates the outcome of Albrecht and O'Brien (1993), that would support the interpretation of Experiment 1 that the L2 learners did not display the contradiction effect.

3. 1. Method

Participants. Twenty-eight undergraduate students at the University of Colorado, Boulder participated in the experiment. They were all native speakers of English.

Materials and Procedure. The materials and procedure were identical with those in Experiment 1 except for the instructions in English. The experiment took approximately 10 minutes.

3. 2. Results and Discussion

The number of incorrect answers of the comprehension questions was counted for each participant. The overall mean incorrect answers were 1.18 (SD = .94) out of 12 questions. None of the participant showed an outstandingly poor performance, and thus the data from all participants were used for analysis. The mean number of incorrect answers for the consistent texts and that

Table 1. *Mean Reading Times(ms) of the Target Sentence from Experiment 1.*

	Condition	
	Consistent	Inconsistent
Target Sentence	5305 (1625)[a]	4887 (1252)
Post-Target Sentence	4237 (1189)	4262 (1218)

[a] Standard Deviation

for the inconsistent texts were 1.32 (SD = 1.00) and 1.04 (SD = .86) respectively. This difference was not statistically significant, $t(27) = 1.25$, $p > .2$.

As with the data from Experiment 1, for each participant, mean reading times for the consistent and inconsistent conditions were calculated after the outlier identification procedure. There were 2 outliers among the target sentence data, which were .5% of all the data points. For the post-target sentences, there were 7 outliers. They constituted 2.1% of the data.

As shown in Table 2, the mean reading time of the target sentence was greater for the inconsistent condition than for the consistent condition. The statistical analysis with participant as a random factor showed that this difference was significant, $t(27) = 1.70$, $p < .05$ (one-tailed), but the analysis with items as a random factor did not, $t(11) = 1.45$, $p > .1$ (one-tailed). As for the post-target sentence, though the mean reading time was greater for the inconsistent condition than that for the consistent condition, this difference did not reach significance by either analysis, $t(27) = .47$, $p > .1$ (one-tailed) by participant analysis, and $t(11) = 1.45$, $p > .1$ (one-tailed).

These outcomes are in agreement with those of Albrecht and O'Brien (1993). Especially, the crucial point is that in this experiment, as in Albrecht and O'Brien's experiments, the contradiction effect was indeed observed with the target sentence that made a contradiction with the earlier part. Therefore, it is legitimate to interpret the results with the L2 participants from Experiment 1 as showing the absence of the contradiction effect rather than showing that the experimental materials and procedure failed to detect the effect. This leads to the conjecture that the L2 participants failed to detect the inconsistency in Experiment 1 presumably because the memory of the elaboration part was no longer accessible due to the intervening sentence.

4. General Discussion

The present study examined whether long-term working memory (LT-WM) plays a role in coherence maintenance during L2 reading. The experiment employed an inconsistency detection paradigm. It is well established in the literature on L1 reading that the reading time of a sentence becomes longer than if it makes a contradiction with an earlier part of the text than if the sentence does not make such a contradiction. The inconsistency effect occurs because the earlier text portion is reactivated and evaluated in light of the currently processed sentence. The experimental results showed that the L2 readers did not display the inconsistency effect even though the contradicting sentences were separated by only a single sentence. Compared to

Table 2. *Mean Reading Times(ms) of the Target Sentence from Experiment 2.*

	Condition	
	Consistent	Inconsistent
Target Sentence	2504 (497)[a]	2651 (621)
Post-Target Sentence	2053 (452)	2106 (808)

[a] Standard Deviation

the results of the L1 study by Albrecht and O'Brien (1993), whose experimental texts had five to six intervening sentences between the contradictory sentences, the extent of text memory access of non-fluent L2 readers appeared to be qutie limited.

What do these results tell us about LT-WM in L2 reading? For the L2 participants, earlier portions of a text, in particular even the sentence that was only two-sentence away from the currently processed one, are not available for the coherence maintenance process. From the point of view of LT-WM, this implies that such information cannot be considered to reside in LT-WM. In other words, it may be argued that the L2 participants were not capable of making use of LT-WM by reactivating the relevant information in LTM. Though this evidence should not be taken as entirely rejecting the role of LT-WM in L2 comprehension, yet it seems tenable to argue that the degree to which LT-WM functions in L2 comprehension is severely limited because of resource limitation, and that the inaccessibility of a functioning LT-WM could cause difficulties for successful comprehension such as the construction of a coherent text representation.

Needless to say, however, it is too soon to conclude that the absence of LT-WM applies to non-fluent L2 readers in general under various text situations. There is a large degree of fluency differences among L2 readers. It is plausible that more advanced learners would display different patterns of results. Another factor that may influence reader performance is that of experimental texts. The lack of reactivation of text memory may be due to some of the characteristics of the experimental materials such as vocabulary, level of structural complexity, and discourse structure. It is conceivable to assume that if texts are easier, the readers could demonstrate a greater degree of memory reactivation.

The present study raises several important questions that should be further investigated.

One is whether L2 readers would display an inconsistency effect if contradicting portions appear adjacently. There may be the possibility that L2 readers do not engage in coherence maintenance processes presumably because of the lack of enough resources. Such evidence would provide further support for the thesis argued in this article. Another questions has to do with the meaning of the lack of inconsistency effect. That is, there are two possibilities for not detecting the inconsistency. One is that the relevant portion is not reactivated. The other possibility is that is is reactivated but is not integrated because reactivation is cosidered to be passive and not resource-demanding, and it is the coherence maintenance process that requires cognitive resources. In fact, Long and Chong (2001) compared between good and poor readers in L1 and presented interesting findings that are relevant to the current study. In their first experiment participants read stories in which a character's action was consistent or inconsistent with a description of the character presented earlier in the story where the description and action were either adjacent in the text (*local coherence*) or were separated by intervening text (*global coherence*). While both groups of participants displayed the inconsistency effect in the local coherence condition, in the global coherence condition, the reading time difference was observed only with the good readers. This means that the inconsistency effect was not found with the poor readers. Their second experiment assessed the availability of the character description at various points in the story by using a probe-verification paradigm. Inerestingly, the researchers found that poor readers, as well as good readers, appeared to reactivate the character description after reading the action. Long and Chong concluded that putting these outcomes together, their study presented a paradoxical picture of poor readers' reading behavior in the sense that they seem to reactivate an earlier text information but fail to integrate it with incoming

information when these pieces of text information are distant. The comprehension processes of L2 readers may be similar to those of L1 poor readers. By answering these questions, it would be possible to have a more detailed and clearer picture of the role and workings of LT-WM during L2 comprehension.

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