Contextual Interference within the Perceptual Span in Reading Japanese Text

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Abstract

In two experiments, we investigated the contextual interference effect within the perceptual span in reading Japanese text by using the moving window paradigm (McConkie & Rayner, 1975). There were four conditions involving different kinds of peripheral text: asterisk, random string, sentence, and control. The results revealed that the efficiency of reading the central text was degraded when the peripheral text consisted of characters irrelevant to the central text (random strings or sentences, Experiment 1). The interference effect was greater when the peripheral text constituted a sentence than when it was a random string (Experiment 2). A word recognition test showed that the words in the peripheral text were processed to some extent. These results suggest that the mere presence of characters in the peripheral region of the perceptual span interferes with the processing of the central text. Furthermore, whether the peripheral text constitutes a sentence also influences eye movements in reading.

Keywords: eye movement; Japanese text; moving window paradigm; perceptual span; reading.

Introduction

Even though the eyes have good visual acuity only in the fovea, information extracted from peripheral areas plays important roles in reading text. The perceptual span in reading is the region from which readers pick up information during a fixation to exploit for reading. The size of the perceptual span, determined by eye tracking experiments using the moving window paradigm, is much larger than the size of the fovea and the parafovea. Reading efficiency is degraded when a smaller region of text than the span is given to readers at one time (Ikeda & Saida, 1976; McConkie & Rayner, 1975; Osaka, 1987).

Eye tracking studies have revealed that information such as phonology (Pollatesk, Lesch, Morris, & Rayner, 1992), orthography (McConkie & Rayner, 1975; White & Liversedge, 2006), and the length of the word in the parafovea (White, Rayner, Liversedge, 2005) is preprocessed and exploited for smooth reading. There are a few studies of information processing in the region outside of the parafovea but in the perceptual span. Information on word spacing is extracted from the region of the perceptual span and influences where to move the eyes (McConkie & Rayner, 1975). In Japanese, an unspaced language with three kinds of scripts (Kanji, Hiragana, and Katakana), the visual distinctiveness of these scripts, instead of word spacing, plays a role in guiding eye movements in reading texts (Kajii, Nazir, & Osaka, 2001).

Is information on word spacing or distinctiveness the only information that is extracted from the region of the perceptual span in reading for guiding eye movements? Basic information on whether there are letters, rather than other kinds of visual stimuli, may be needed for reading. Furthermore, information on whether the letters constitute a sentence may also matter. Not only information about word spacing but also about the general configuration of the sentence may be used for guiding the eyes. People often feel that they can tell in a brief look whether a visually presented object is a letter or something else (e.g., a symbol), or whether a letter string is meaningful text or a meaningless random string. It is possible that these kinds of information influence the control of eye movements.

In this study, we investigated the extent to which information from all over the region of the perceptual span is used for reading Japanese text. We had two hypotheses, as follows. (1) Do characters in the non-foveal region of the perceptual span influence reading efficiency? (2) If so, does whether the characters constitute sentences have an influence on reading efficiency? Three kinds of Japanese scripts are used together in writing meaningful texts, and the visual distinctiveness of them plays a role similar to word spaces in spaced languages such as English (Kajii, et al., 2001). This means that random strings made of Japanese Kanji, Hiragana, and Katakana have information that can be used like word spacing, although they have no configuration that looks like sentence. By using Japanese text as stimuli, we could manipulate whether there was a sentence or not in a region of the perceptual span independently of word spacing.

We employed the moving window paradigm (McConkie & Rayner, 1975). This method replaces the display in a certain region around the reader's current fixation point with letters from the original text. The region of the original text changes contingently with the eye movements. Namely, the participant reads the original text through a 'window'. The influence of a relatively wide region of peripheral text on the foveal reading processing can be investigated by using this paradigm. In our study, participants read central text through a three-character-width window. The text outside of the window was replaced by other (peripheral) text. The perceptual span in reading Japanese is about 12-13 characters long (Ikeda & Saida, 1976; Osaka, 1987). By

【Central Text : 奇跡的に手術は成功し、彼女は順調に回復していった。】

↓ Participant's current point of fixation

Control : 奇跡的に手術は成功し、彼女は順調に回復していった。

Asterisk : ＊＊＊＊＊＊は成功＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊＊

Random Strings: でた調いのもは成功て遊冬、込一か日のにた隣はも日。

Sentence : 私の父は、いは成功茶を砂糖もミルクも入れずに飲む。

Figure 1: An example of a central stimuli text and various peripheral texts.
Note. The central text and the control condition text above mean "The operation was miraculously successful, and she got well". The peripheral text used in the sentence condition above means "My father always drinks tea without sugar or milk".

presenting the central text only in a very small region in the perceptual span, we made it likely that participants would process the peripheral text in reading. This allowed us to study the interference effect of processing different peripheral texts on the central text.

There were four conditions of peripheral texts: asterisk, random string, sentence, and control (see Figure 1). In the asterisk condition, no available or distractive information is given as peripheral text. If information from characters in the peripheral text matters in reading, the interference effect of the peripheral text in the random string and the sentence conditions would be greater than in the asterisk condition. If only distribution information from the three kinds of Japanese scripts were extracted and used for word spacing, the reading efficiency of the central text would be equally degraded in both the random string and the sentence conditions, because the distribution of the kinds of scripts could mislead eye movements. If information about whether the peripheral characters constitute a sentence were extracted, as we hypothesized, the interference effect would be greatest in the sentence condition. This would be because not only the script distribution in the peripheral text, but also the sentence structure which is irrelevant to the central text, would be processed and used for guiding the eyes.

Experiment 1

Method

Design We used a within-participant one-way design with four peripheral text conditions: asterisk, random string, sentence, and control (normal reading condition with no window). Reading time for the central text was measured. Eye movements were also analyzed. A sentence comprehension test was given in each trial in order to ensure that participants read the central text with good comprehension. After the experimental session was finished, a recognition test for words that appeared in the stimulus texts (central and peripheral texts) was conducted.

Participants Twenty Japanese native speakers, between 20 and 27 years old, with normal or corrected-to-normal vision participated in this experiment. They were tested with a vocabulary estimation test (NTT Communication Science Laboratories, 1999), and all had normal Japanese vocabularies.

Apparatus Stimuli were displayed at the center of a monitor (Sony Trinitron MultiScan G520) controlled by a computer with a visual stimulus generator graphics card (Cambridge Research Systems VSG 2/5). Reading times were measured from the onset of the target stimuli by means of a digital millisecond timer. Left eye movements were monitored using a dual Purkinje eye tracker (Cambridge Research Systems Video Eyetracker Toolbox 2.10). The resolution of the eye tracker was 0.025 degree and the sampling rate was 50Hz.

Stimuli Sixty 25-character Japanese texts were used as central text stimuli. They consisted of Kanji, Katakana, and Hiragana characters in a typical text distribution. Each central text stimulus was paired with a peripheral text of the same length (25 characters). Three characters of the peripheral text around the participant's current point of fixation were replaced with the characters of the central text in the corresponding positions (see Figure 1). Thus, participants always read the central text through a three-character-window created in the peripheral text paired with it.

There were 15 trials for each of the four peripheral text conditions (asterisk, random string, sentence, and control). In the asterisk condition, the peripheral text consisted of 25 asterisks. In the random string condition, the peripheral text consisted of characters chosen randomly from the characters used for the 60 central texts. The random strings had no meanings or meaningful words in them. In the sentence condition, the peripheral text was normal Japanese text, paired with the central text so that there was no semantic relationship between their meanings. The random strings and sentence peripheral texts consisted of Kanji, Katakana and

Hiragana in approximately the same distribution as the central texts. In the control condition, the peripheral text was the same as the paired central text. Namely, there was no apparent window and the whole central text was always displayed, like normal reading.

To make sure that participants read the texts with comprehension, an easy comprehension test was administered at the end of each trial. The participants were asked a Yes or No question about the central text.

All the characters were displayed in MS Gothic (Japanese fixed-width font). Each character subtended a visual angle of 1.01 degree horizontally and vertically. The stimuli texts were written horizontally in black on a white display.

Procedure Each participant was seated in front of the monitor in a quiet room. A head and chin rest was used to maintain a viewing distance of 57 cm. Participants responded using a response key box connected to the computer.

Prior to beginning the experimental session, participants engaged in a calibration task. Eight practice trials were given.

At the beginning of each experimental trial, 25 crosses (+) in a horizontal row appeared for 300 ms as a fixation at the center of the screen. Immediately after the offset of the fixation, a stimulus text was presented. The four peripheral conditions appeared in random order. Participants were required to read the text silently and to press a key as soon as they finished reading. Reading time was measured from the onset of the stimulus text to the key press response. When the response was made, or 15 s had passed since the onset of the sentence without any response, the stimulus text disappeared. Finally, a question was presented 1000 ms after the disappearance of the stimulus text. Participants were required to read the question silently and to answer using the key press. If the response was incorrect, auditory error feedback was presented. The question disappeared after the response was made. The next trial began when participants made another key press. The experiment consisted of one block with 60 trials.

After all the trials, a recognition test for the words that appeared in the stimulus texts (both central and peripheral texts) was administered; participants had not been informed about this testing beforehand. Participants were shown 60 words on a sheet of paper: 20 words appeared in the central texts, another 20 appeared in the peripheral texts, and the other 20 did not appear in the experiment. Participants made recognition judgments for each of the words on a five-point scale of confidence from 1 (certain that the word is old) to 5 (certain that the word is new). The entire experiment took about 45 minutes.

Data Analysis The mean reading times for the central text, the scores for the comprehension test, and the ratings on the word recognition test were analyzed.

Eye movements were also analyzed: numbers and durations of fixations, numbers and length of saccades (forward and backward), and regression rates (ratio of backward saccades to all saccades) for each of the text stimuli. A saccade was defined as an eye movement that exceeded the width of a character (1.01 degree) within 20 ms. A fixation was defined as a period of time when an eye did not move more than the width of a character in 100 ms or longer.

Results

Only the data from the trials in which the participant finished reading the text stimuli within the time limit were used for the analysis. Recognition judgments for the words that appeared in trials in which the answer for the sentence comprehension test was incorrect were also eliminated from the data analysis of the recognition test. Repeated measures one-way ANOVAs were used for the analyses.

Reading Time and Comprehension Test Figure 2 shows the results for the mean reading time per text. There was a main effect of peripheral text, $F(3, 57) = 264.41$, $p < .01$. Tukey's HSD tests revealed that there was a significant difference for every paired comparison for all of the conditions (all *p*s < .01), except between the random string and the sentence condition (the difference between these two conditions was marginally significant, $p = .08$). This means that reading was slowed down when the peripheral text was unavailable for reading, and the interference effect was greater when the peripheral text consisted of characters irrelevant to the central text (the random string and the sentence conditions). Whether the peripheral text constituted a sentence (compared to a random string) did not result in a clear effect.

The scores on the central text comprehension test were excellent (over 95% correct in all conditions) and there was no main effect of peripheral text. Thus, participants read the central text with equally good comprehension in all conditions.

Eye Movement Data Figure 3 shows the results for the mean number of fixations per text (a) and the mean fixation durations (b). The main effect of peripheral text was significant for the number of fixations, $F(3, 57) = 32.33$, $p < .01$. Tukey's HSD tests revealed that there was a significant difference for every paired comparison for all of the conditions (all *p*s < .01), except between the random string and the asterisk conditions, and the random string and the sentence conditions (the difference between these two conditions was marginally significant, $p = .07$). These results suggest that more fixations were made in the asterisk, random string, and sentence conditions than in the control condition, and the number of fixations was the largest in the sentence condition. A main effect of peripheral text was also observed for the mean fixation duration, $F(3, 57) = 62.39$, $p < .01$. Tukey's HSD tests revealed that there was a significant difference for every paired comparison for all of the conditions (all *p*s < .01), except between the random string and the sentence conditions. This means that the fixation duration was longer when the peripheral text was unavailable for reading, and was longest when the

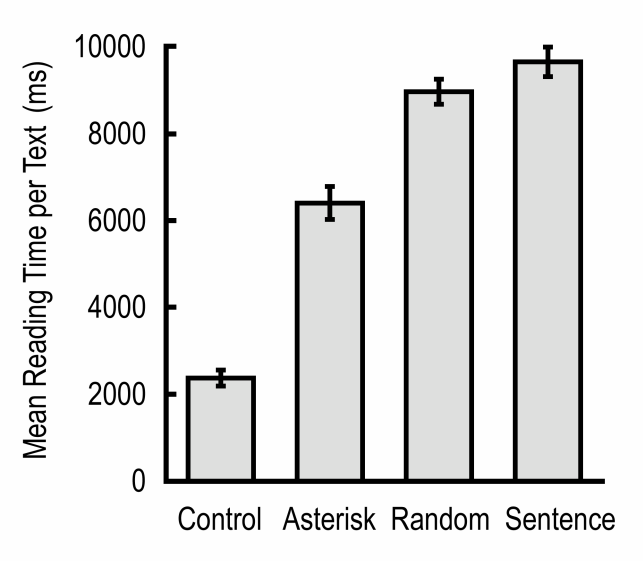

Figure 2: Mean reading time per text in Experiment 1. Error bars represent standard errors.

peripheral text consisted of characters irrelevant to the central text.

Briefly reporting the other eye movement results, saccades (both forward and backward) were longer and more frequent in the asterisk, random string, and sentence conditions than in the control condition. Furthermore, the number of backward saccades and both the forward and backward saccade lengths were significantly different between the non-character (control, asterisk) and the character (random string, sentence) conditions. The regression rate was also higher in the character than in the non-character conditions. However, an effect of whether the peripheral text was a sentence, which should be observed as differences between the random string and the sentence conditions, was only sometimes marginally significant, and was not clearly evident.

Word Recognition Test There was a main effect of the kind of word, $F(2, 38) = 176.15$, $p < .01$. Tukey's HSD tests revealed that there was a significant difference for each of the paired comparisons of the three conditions: central, peripheral, and new (all *p*s < .01). This means that the words that had appeared in the central text were judged as "old", and those that had not appeared in the experiment were judged as "new" with relatively good confidence (mean ratings: 1.70 and 3.74, respectively). Furthermore, participants were significantly less confident in judging the words that had appeared in the peripheral text as "new" compared to the new words (mean rating: 3.26).

Discussion

Most of the data revealed that reading slowed down and became less fluent when the peripheral text was unavailable for reading, especially when the peripheral text consisted of characters irrelevant to the central text (the random string and the sentence conditions).

Whether the peripheral characters constituted a sentence had a weak effect, which was only sometimes marginally significant. The results of the word recognition test, however, suggest that the words in the peripheral text were processed to some extent.

The results suggest that there were considerable differences in the easiness of reading between the non-character (control, asterisk) and the character (random string, sentence) conditions. This difference might have caused a switching of strategy or task set in reading, or difficulty in controlling eye muscles. It is possible that this made the data noisy enough to bury an effect of whether the peripheral text constituted a sentence, which might have appeared as relatively small differences. To avoid this problem, we reduced the conditions to two in Experiment 2: the random string and sentence conditions.

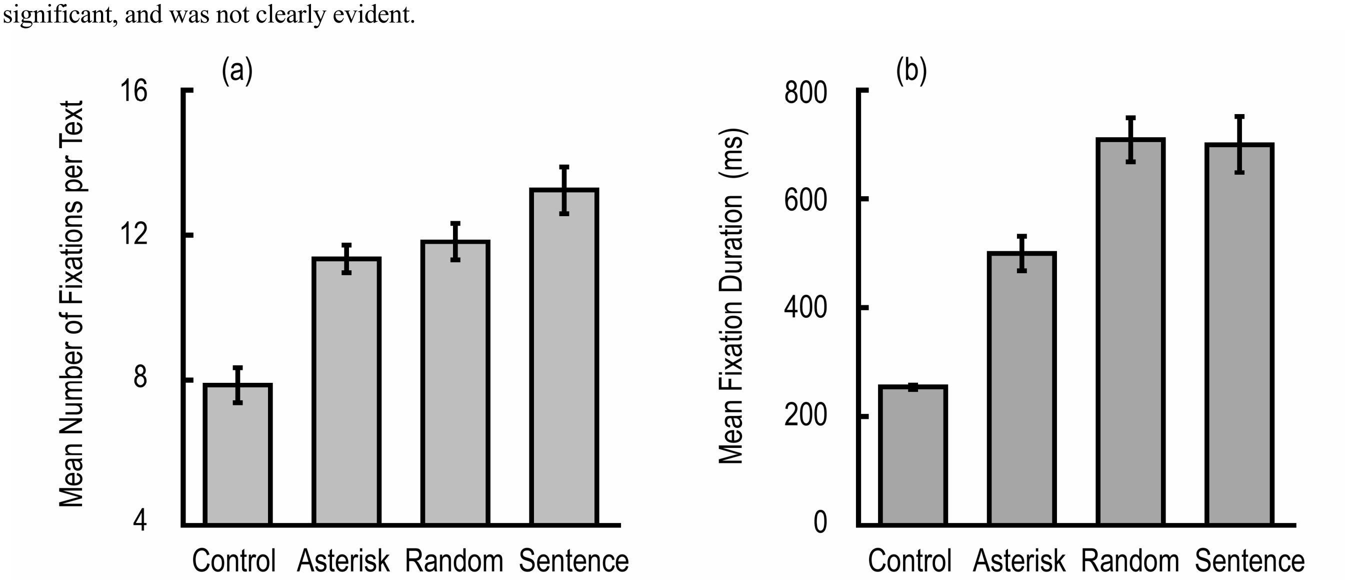

Figure 3: Mean number of fixations per text (a) and mean fixation duration (b) in Experiment 1. Error bars represent standard errors.

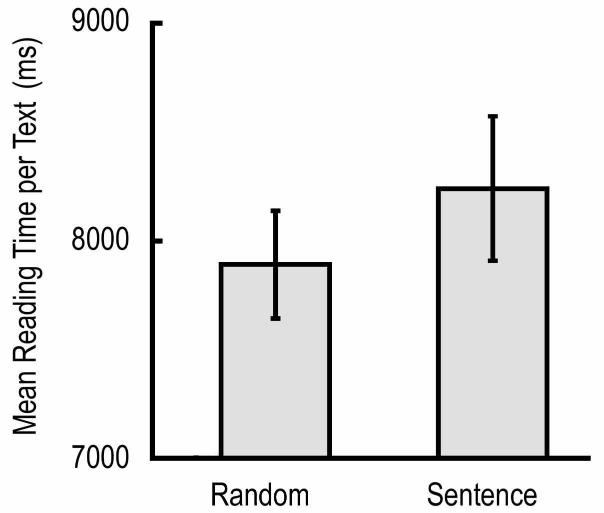

Figure 4: Mean reading time per text in Experiment 2. Error bars represent standard errors.

Experiment 2

Method

Design We used a within-participant one-way design with two peripheral text conditions: random string and sentence. The basic method was the same as in Experiment 1, except that there were only the random string and the sentence conditions.

Participants Twenty Japanese native speakers (between 20 and 30 years old), who had not participated in Experiment 1, participated in this experiment. They fulfilled the same criteria as in Experiment 1.

Stimuli Sixty 25-character Japanese texts, which were the same as those used in Experiment 1, were used as central text stimuli. Half of the text stimuli were assigned to the random string condition, and the remaining half were assigned to the sentence condition.

Results

Reading Time and Comprehension Test Figure 4 shows the results for the mean reading time for each text condition. There was a significant main effect of peripheral text, $F(1, 19) = 7.74$, $p < .05$. This means that participants took more time in reading the central text in the sentence condition than in the random string condition. Thus, an effect of whether the peripheral text constituted a sentence was clearly observed.

The scores on the central text comprehension test were excellent (over 96% correct in both conditions) and there was no significant difference between the two conditions. Thus, participants read the central text with equally good comprehension in both conditions.

Eye Movement Data Figure 5 shows the results for the mean number of fixations per text (a) and the mean fixation durations (b). A main effect of the peripheral text was significant for the number of fixations, $F(1, 19) = 11.94$, $p < .01$. This suggests that there was an effect of whether the peripheral text constituted a sentence or not on the number of fixations. A main effect of peripheral text was not significant for the mean fixation duration.

The results for the number of saccades (both forward and backward) also showed significant or marginally significant differences between the random string and the sentence conditions. There were no significant differences between

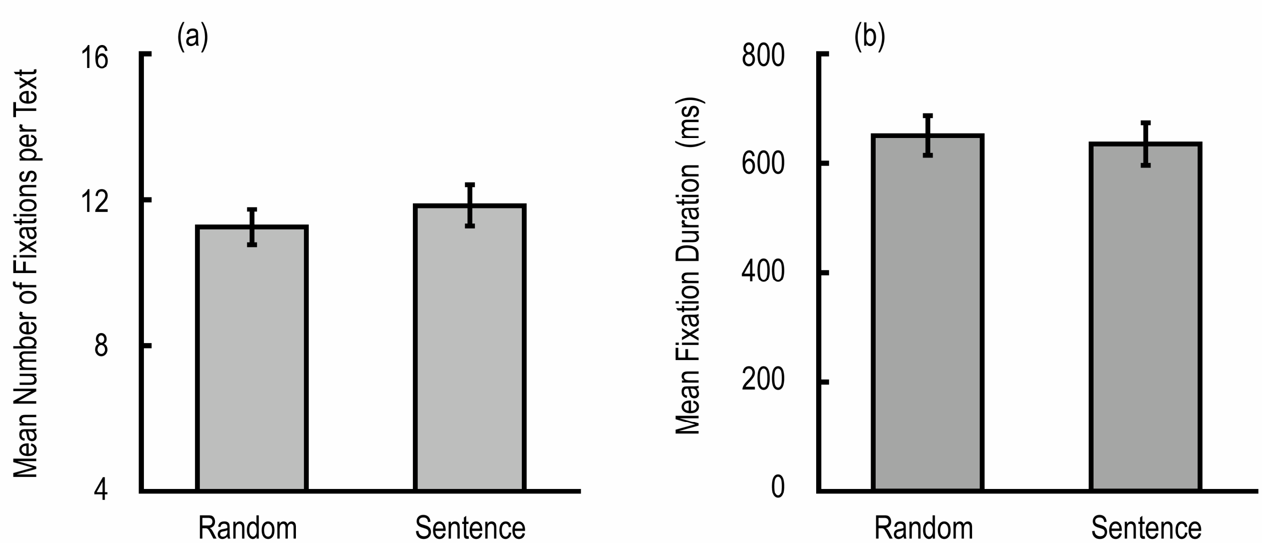

Figure 5: Mean number of fixations per text (a) and mean fixation duration (b) in Experiment 2. Error bars represent standard errors.

these two conditions in the results for the saccade length or the regression rate.

Word Recognition Test There was a main effect of the kind of word, $F(2, 38) = 204.59$, $p < .01$. Tukey's HSD tests revealed significant differences for every paired comparison among the three conditions: central, peripheral, and new (all *p*s < .01 except $p < .05$ for between the peripheral and the new conditions; ratings: 1.49, 3.36, and 3.69, respectively). This means that participants were significantly less confident in judging the words that had appeared in the peripheral text as "new" compared to the new words, as was also found in Experiment 1.

Discussion

The results in Experiment 2 showed an effect related to whether the peripheral text constituted a sentence. Irrelevant peripheral sentences interfered more than random strings with reading the central text. The results for fixations and saccades suggest that the eyes moved and re-fixated on characters more frequently in the sentence condition, without an increase in fixation duration, saccade length, or regression rate.

General Discussion

In the two experiments reported here, we investigated contextual interference within the perceptual span in reading Japanese text using the moving window paradigm (McConkie & Rayner, 1975). Reading time for the text, eye movements, and word recognition were measured. The data revealed that the efficiency of reading central text was degraded when the peripheral text consisted of characters (random string and sentence conditions, Experiment 1), and the interference effect was greater in the sentence condition than in the random string condition (Experiment 2). The results from the word recognition tests showed that the words in the peripheral text were processed to some extent.

These results suggest that the mere presence of characters in the perceptual span in reading influences the processing of the central text. Furthermore, whether the peripheral text constituted a sentence influenced eye movements in reading.

An effect of whether the peripheral text constituted a sentence was observed in the results for fixations and saccades. These results suggest that eyes moved and re-fixated on characters more frequently in the sentence condition than in the random string condition, without an increase in fixation duration, saccade length, or regression rates. This contrasts with the effect of the mere presence of characters, which was also observed to increase fixation duration and saccade length. A possible explanation for this is that the "mere presence of characters" and "whether the characters constitute a sentence" in the peripheral text differ in the level where they influence reading. Visual information for eye guidance may be extracted from the "mere presence of characters" former, while higher-level information such as lexical, syntactic, pragmatic, or semantic for reading comprehension may be obtained from "whether the characters constitute a sentence". Further research is needed to clarify this issue.

It seems surprising that whether the peripheral characters constituted a sentence had only a relatively small effect. This suggests that readers can suppress information within the perceptual span, which they usually exploit for reading, if it is judged as distractive for the current reading task.

The present study cannot answer the question about which aspects of "the peripheral text that constitute a sentence" affect the reading of the central text. One possibility is the words by themselves affect the reading. Another possibility is that the characters construct a meaningful or syntactically correct sentence. Considering that visual acuity is poor in the peripheral visual field, the latter possibility seems less plausible. We also had conducted an experiment the same as Experiment 1 except that the window size was five characters wide. The results were approximately the same as reported here for Experiment 1, with smaller effects related to whether the peripheral text constituted a sentence. This result also casts doubt on the latter possibility because it suggests that only the parafoveal information was extracted and influenced the reading. Further study is needed to clarify the function and the characteristics of the influence of a "sentence" on the perceptual span of reading.

Acknowledgments

The authors wish to thank Ms. Kotomi Tanbo at the University of Tokyo for her help in conducting this research.

References

Ikeda, M., & Saida, S. (1978). Span of recognition in reading. *Vision Research, 18*, 83-88.

Kajii, N., Nazir, T. A., & Osaka, N. (2001). Eye movement control in reading unspaced text: The case of the Japanese script. *Vision Research, 41*, 2503-2510.

McConkie, G. W., & Rayner, K. (1975). The span of the effective stimulus during a fixation in reading. *Perception & Psychophysics, 17*, 578-586.

NTT Communication Science Laboratories (1999). *Goisu suitei tesuto* [Vocabulary estimation test]. Retrieved on 01/15/2006, from http://www.kecl.ntt.co.jp/icl/mtg/goitokusei/goi-test.html

Osaka, N. (1987). Effect of peripheral visual field size upon eye movements during Japanese text processing. In J. K. O'Regan & A. Levy-Schoen (Eds.), *Eye movements: From physiology to cognition*. Amsterdam: North-Holland.

Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 148-162.

White, S. J., & Liversedge, S. P. (2006). Foveal processing difficulty does not modulate non-foveal orthographic influences on fixation positions. *Vision Research, 46*, 426-437.

White, S. J., Rayner, K., & Liversedge, S. P. (2005). The influence of parafoveal word length and contextual constraint on fixation durations and word skipping in reading. *Psychonomic Bulletin & Review, 12*, 466-471.