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The proofreading of Japanese sentences: visual, phonological, and semantic processing

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はじめに

文章校正は、視覚情報処理能力や意味情報処理能力などを駆使して行われ、そのパフォーマンスには、高次理解過程、知識、記憶など様々な要因が影響していると考えられる。本報告では、その中で日本語特有の漢字の処理に関わる視覚的要因、音韻的要因、意味的要因の3つをとりあげた。本報告は、Part1、Part2の2つに分かれている。Part1は、視覚的要因について検討した2つの実験をまとめた論文である。Part2は、音韻的要因、意味的要因をそれぞれ調べた2つの実験のShort Reportである。

Part1では、文章校正時の視覚的処理、特に（1）人はどの様な単位で誤字を探しているか、（2）どの様な特徴を利用して誤字を探しているか、という2つの問題に答えるために実験を行った。第1の問題を調べるためには、継時分割提示法を用いて、刺激の提示単位を操作した。すなわち、文章を1文字、単語、文節、全文の4つの条件で継時提示した。第2の問題を調べるためには、誤字と正字の形態類似性を操作した。

実験の結果、2つの問題に対してそれぞれ以下のような答えが得られた。

（1）単語・文節単位で提示したとき、1文字単位で提示したときよりも、誤字検出が促進された。また、通常の読文時のような読み方で誤字を探す被験者に関しては、文章単位で提示したとき、単語・文節単位で提示したときに比べて、誤字検出が抑制された。この結果は、課題に理解テストを加えて被験者の読み方を統制することによって、より明らかになった。さらに、検出時間の分析から単語、文節程度の単位であれば、並列処理が行われていることが示された。これらの結果は、単語が読文時の処理ユニットであるという従来の理論（Unitization hypothesis, Healy et al.）と一致し、人は文章校正の際にも、単語や文節といった1文字よりも大きな単位の情報を用いて文章を読んでおり、そのことが、日常経験する文章校正の難しさの原因でもあると考えられる。

（2）類似誤字の検出率は非類似誤字に比べて25%も低く、人は誤字検出時にも、必ずしも文字を詳細に処理しているのではなく、概形的な特徴を利用していることが明らかになった。

Part2では、実験1で音韻的要因について、実験2で意味的要因について調べた実験の結果を報告する。音韻的要因を調べるために、正字と誤字の発音の同一性を、意味的要因を調べるためには、誤字が単語中にあるか非単語中にあるかという語彙性を操作した。実験の結果、発音、語彙性ともに、検出率にはほとんど影響を及ぼさないことがわかった。その反面、両者とも検出時間には大きな影響を及ぼし、正字と発音が異なる誤字よりも同じ誤字が、また単語中の誤字よりも非単語中の誤字の方が速く検出されることが明らかになった。

一連の実験より、視覚的要因は誤字検出の正確さに、音韻的要因と意味的要因は誤字検出の速さに影響することがわかった。

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Part 1

The effects of visual similarity and display units on the proofreading of Japanese sentences

Proofreading is defined as a detection task in which targets are not predesignated but determined by the context. Subjects are asked to search for target misspellings which are inappropriate in the context. Rayner & Pollatsek (1989) referred to proofreading as an example of nonstandard reading. They said that people can engage in various forms of reading in which their search processes may be different from when they normally read a text book. However, there are only a few findings about the search process in proofreading (Healy, 1980, 1981b; Healy & Drewnowski, 1983; Monk & Hulme, 1983). Most of the research on proofreading has used a variant of the letter-detection task in which subjects search for all instances of a given target letter or target word (Rayner & Pollatsek, 1989).

One aim of the present study is to investigate the search process in proofreading, especially, to determine what the processing units are. As for the letter-detection task, there are some interesting studies to determine which units are used in reading text by revealing which constituents are ignored by the readers (Healy, 1981a). For example, subjects searching for target letters such as *t* in passages made more detection errors on familiar words such as *the* than unfamiliar words such as *thy* (Healy, 1976; Drewnowski & Healy, 1977). The target letters in correctly spelled words were missed more often than those in misspelled words, and there was no difference in detection error between familiar and unfamiliar words when they were misspelled (Healy & Drewnowski, 1983). These findings showed that familiar words such as *the* are processing units in reading, and misspelled words are not.

The unitization hypothesis (Drewnowski & Healy, 1977) is consistent with these findings. The crucial assumptions of the unitization hypothesis are as follows. There exist processing units, such as letters, syllables, and words. Once a word is identified, the processing of its constituent letters stops, even if the letters have not yet been identified. When people read sentences for meaning, they move on through a text even if they do not identify the constituent letters. The same processes occur in the letter-detection task, because the comprehension processes are conducted automatically (Healy, Oliver, & McNamara, 1987). However, when target letters are embedded in misspelled words, the processing in terms of word-level units is disturbed for misspelled words and subjects give attention to constituent letters (Healy, 1981a).

In the previous studies (Healy, 1980; Healy & Drewnowski, 1983), proofreading experiments were conducted to compare with a series of letter-detection experiments. In both proofreading and letter-detection in misspelled words, letter detection for familiar words were easier than in letter-detection in correctly spelled words. This showed that the processing in word-level units were disturbed for the misspelled words, and subjects would be likely to process constituent letters. From this findings, however, it is not clear whether or not the same search process occurred in proofreading and letter-detection. Two possible explanations are considered. One possibility is that, in proofreading, the subjects read sentences in word-level units, and processed only misspelled words in letter-level units. The other is that the subjects searched for misspellings using only letter-level units in proofreading. To investigate this issue, we manipulated the size of presentation units by employing a variant of the rapid sequential visual presentation method (Forster, 1970; Joula, Ward, & McNamara, 1982). This method reveals in which unit people tend to ignore misspellings.

Another aim of this study is to determine whether or not word-shape or a supraletter feature is utilized for proofreading. Some studies (Healy, 1981b; Monk & Hulme, 1983) have demonstrated that visual similarity between the correct letter and the misspelled one increased the detection error. It was reported that misspellings that maintained word shape were less noticeable than those did not. However, Healy & Drewnowski (1983) found inconsistent results, and much more detection errors were shown in some different-shape misspellings than in same-shape misspellings in their Experiment 2. They accounted for these inconsistent results by noting the incomplete definition of letter shape similarity. There needs to be a wide range of visual similarity between the misspelled constituent and the correct one.

We used Japanese sentences and characters, because there are two important differences between written English and Japanese which contribute to the achievement of the two aims of this study. First, there are spaces between words in English, but not in Japanese. In English, a word is considered to be the visual processing unit (e.g., Drewnowski & Healy, 1977). In Japanese, on the other hand, the processing unit is visually ambiguous. Therefore, it is possible to manipulate the size of presentation units right down to one character, which is the minimum orthographic unit. In our experiments, there were four kinds of presentation units: sentence, phrase, word, and characters. The constraints of the context became stronger as the size of presentation units increased. Healy, Oliver, & McNamara (1987) conducted letter-detection experiments using a similar method, a variant of rapid sequential visual presentation, in order to investigate the effects of display size on the processing of constituents. They systematically manipulated the number of words in view, but did not consider the meaningfulness of the display units. The process of reading sentences includes sentence segmentation based on lexical and syntactical knowledge, and performance may be affected by semantic context in proofreading. Thus, we employed semantic segmentation in the present study.

The second difference is that the Japanese writing system has many more characters than the twenty-six letters of the English alphabet. Moreover, there are many character pairs which are visually similar in Japanese writing. Thus, it is easy to obtain a wide range of visual similarity. Figure 1 shows a typical Japanese sentence and examples of similar character pairs.

Experiment 1

Method

Subjects. The subjects were twenty-four native Japanese adults. All subjects reported having normal or corrected-to-normal vision.

Apparatus. Stimuli were presented by a CRT tachistoscope under the control of a personal computer (NEC PC-9801). This tachistoscope draws a pattern using a random scan method, and features a fast-decay phosphor (p31) which decays to 10% intensity at .09 msec after display offset.

Design. We used a three-way design with within-subject factors: visual similarity of stimuli (similar or dissimilar), presentation unit (sentence, phrase, word, or character), and display duration (100 msec, 250 msec, or 400 msec per character). The duration 250 msec per character nearly corresponds to normal reading speed. Two dependent variables were examined: detection rate and latencies for correct responses.

Materials. 240 simple Japanese sentences were constructed. They had a mean length of 36.5 characters, with a minimum of 31 and maximum of 40. Each sentence included one base *Kanji* word (i.e., a correctly spelled word). All base words were nouns between two and four characters in length. In Japanese writing, content words such as nouns are usually written in Kanji characters, which are ideographic. On the other hand, function words are usually represented by *Kana* characters, which are syllabic. Sentences usually consist of several phrases which in turn usually consist of one content word and some function words.

In yes-trials, a character included in a base word was substituted by another character (i.e., misspelled character) to construct a misspelled word. "Misspelling" in Japanese is defined as employment of existing but incorrect characters. Misspelled words were generated by using (1) incorrect but visually similar characters (i.e., similar misspellings), (2) incorrect but visually dissimilar characters (i.e., dissimilar misspellings). In other words, all of the misspelled characters are real Kanji characters, and the misspelled words are nonwords. As for visual similarity, a quantitative measure was used (See Appendix). The position of misspellings was not controlled. The misspellings appeared in the third position in the sentence at the earliest and in the thirty-sixth position at the latest. Subjects were informed that misspelled words were always nouns represented by Kanji characters and that a sentence would include no more than one misspelling.

Procedure. Each subject was individually tested in 240 trials in a private room. Half the trials were yes-trials, in which a sentence included a misspelling, and half were no-trials, in which a sentence did not include a misspelling. Half of the yes-trials included similar misspellings and half included dissimilar misspellings. By counter-balancing across subjects, all sentences were assigned in all conditions with the same frequency.

We employed the moving rapid sequential visual presentation method (Sinclair, Healy, & Bourne, 1989). In this method, the units were presented one at a time in the position they would occupy in a normal sentence. Four presentation units were used: sentence, phrase, word, and character. There were three display durations: 100 msec, 250 msec, and 400 msec. That is, a character (or word, phrase, sentence) was presented one at a time for 100 msec (or 250 msec, 400 msec) per character. For example, when a word consisting of three characters was presented in word presentations of 100-msec duration, it was presented for 300 msec. A sequence of events in each trial is as follows. At first, dots were presented, which showed the position where stimulus sentences appeared. Then, stimulus sentences were presented on two lines by replacing one dot with one character (Figure 1). The first line included about twenty characters. The rest of the characters in a sentence were presented on the second line. The lines were separated between phrases. The dots remained at the position except for a character(or word, phrase) which were then presented, to guide eye movement. In character, word, and phrase presentations, measurement of response latencies started when the misspelling was presented. In sentence presentations, measurements began when the sentences were presented. The subjects were told to push the right-hand button as quickly as possible when they found a misspelling. They were also told to push the left-hand button when they decided that a sentence had no misspelling. The sentence disappeared soon after the subjects' response. After pushing the right-hand button, the subjects were asked to write down the misspelling they found. It should be noted that they were told that they could write a misspelled character, a base word, or any cues which showed the misspelling. When they finished writing, they pushed either button. Then, the next sequence was begun. After all trials, the subjects were tested on their knowledge of words with similar Kanji.

Stimuli were presented to the subjects from a viewing distance of 115 cm. A character occupied a visual angle of about .6°, and a line occupied a visual angle of about 12.4° at most. The distance between the bottom of the first line and the top of the second line occupied a visual angle of about .7°.

Results and discussion

Correct detection. On the basis of the knowledge test, seven of the stimuli were excluded from analyses. The position of misspellings in sentences did not show either consistent or significant difference in detection rate.

The mean detection rates were computed as a function of three conditions. The results are shown in Table 1. We conducted a three-way analysis of variance (ANOVA) including all three conditions. Overall, the main effects of stimulus similarity, presentation unit, and display duration were significant [$F(1, 23)=186.4$, $p<.001$; $F(3, 69)=26.9$, $p<.001$; $F(2, 46)=121.2$, $p<.001$, respectively]. The interaction between presentation unit and display duration was also significant [$F(6, 138)=13.6$, $p<.001$]. Dissimilar misspellings could be detected about 25% more accurately than similar misspellings. Moreover, subjects detected more misspellings for larger presentation units and longer display durations. The interaction between presentation unit and display duration is as follows.

In the 100-msec duration trials, both similar and dissimilar misspellings were detected more accurately for larger presentation units [$F(3, 23)=19.4$, $p<.001$; $F(3, 23)=21.3$, $p<.001$, respectively]. The results of the 250-msec duration trials were consistent with the 100-msec duration trials. The differences depending upon the presentation unit in the 250-msec duration trials were smaller than in the 100-msec duration trials for both stimulus similarity conditions. For similar misspellings, there was no significant difference, but for dissimilar misspellings the difference between sentence and character presentations was significant [$F(3, 23)=3.7$, $p<.05$].

The most interesting results were found in the 400-msec duration trials. Different patterns of results were shown for similar and dissimilar misspellings. The accuracy of dissimilar misspelling detection for each presentation unit was almost the same. On the other hand, similar misspellings were detected more accurately in phrase and word presentations than in sentence and character presentations, although these differences were not statistically significant. This result suggests that the processing in terms of word-level or phrase-level unit has an advantage. One possible explanation for the lack of significant differences in the present experiment is that in sentence presentations subjects might not read sentences from the beginning to the end in order, but may regress in a sentence or search for misspellings in a random method.

To test for this possibility, response latencies for sentence presentations were analyzed by subject. We divided the subjects into three eight-subject groups on the basis of the mean response latencies of each subject: faster, medium, and slower. The mean latencies in each group were computed as a function of the position of the misspelling in a sentence. The results showed that the later the misspelling appeared in a sentence, the longer the latencies were. The correlation coefficients were the highest (r=.83) in the faster group. However, in the medium and slower groups the correlation coefficients were relatively low; in the medium group r=.45, and in the slower group r=.56. These results suggest that subjects in the faster group read a sentence from the beginning to the end in order. In the medium and slower groups, on the contrary, it is assumed that subjects did not read the sentence in order. On the basis of the response latencies, the results of detection rate in the 400-msec duration trials for similar misspellings were reanalyzed. In the slower group, no difference was evident among presentation units. On the other hand, in the faster group, word presentations made the most accurate detection and sentence presentations showed the least accuracy. The difference in the faster group was large (23.8%), but not statistically significant because of the small data set. Accordingly, when the display duration was sufficient and subjects read the sentence in order, misspelling detection was most accurate in word presentations.

Response latencies. The mean latencies of the correct responses are shown in Table 1. We conducted a three-way ANOVA with all three conditions. Only the main effect of presentation unit was significant [$F(3, 69)=99.0$, $p<.001$]. The result showed that subjects detected misspellings more slowly in sentence presentations than in word and phrase presentations, and faster in word and phrase presentations than in character presentations. The extremely long latencies in sentence presentations may be caused by the fact that the measurement of response latency began at the time the units with misspellings were presented. The misspelling position deviation in sentence presentations between the third and thirty-sixth was larger than that in other presentations between the first and sixth. Thus, there is not much point comparing the latencies in sentence presentations with those in other presentations. On the other hand, the fact that the latencies in character presentations were longer than those in word and phrase presentations suggests the interesting process in proofreading. In character presentations, at the moment a misspelling was presented, subjects could not decide whether it was a misspelling or not. The misspellings could be detected only after the subjects read some more characters.

One of our interests is how constituents in words are processed. In the present experiments, if characters were serially processed, the accuracy in phrase and word presentations would be equal to that in character presentations, because the display duration per character was the same for all presentation units. In fact, even in the 100-msec duration trials, misspellings were detected more accurately in phrase and word presentations than in character presentations. As for word and phrase presentations, the means of the response latencies were also computed as a function of the number of characters and the position of the misspellings in a unit. One-way ANOVA's showed that neither factor affected response latencies. Thus, we concluded that characters in phrases and words were processed in parallel. Combining these findings with the results that accuracy of misspelling detection is higher in word or phrase presentations, it is postulated that words or phrases are processing units in the proofreading of Japanese sentences.

Experiment 2

Experiment 1 showed that when the display duration was sufficient, there was a tendency towards facilitating the processing of constituent characters in word and phrase presentations, and disrupting it in sentence presentations. It was assumed that the lack of a substantial difference in detection rates was caused by the subjects' reading strategies. In Experiment 2, to control the subjects' reading strategies, a comprehension task was added, because it is assumed that subjects who were asked to understand the meaning of text would read a sentence from the beginning to the end.

Method

Subjects. Subjects were twenty-four native Japanese adults who did not participate in Experiment 1.

Design, Apparatus, and Materials. The same experiment design, apparatus and materials as in Experiment 1 were used.

Procedure. The general procedure was the same as in Experiment 1, except that stimuli were presented to the end of sentences even after subjects' responses and that a comprehension task was added. Subjects were told that they should read stimuli to the end even after they found misspellings and responded. In each trial, after subjects' response about the misspellings, a short sentence was presented. Subjects were asked to decide whether or not the content of this short sentence and that of stimulus sentence were consistent. If they were consistent, subjects had to push the right-hand button. If they were inconsistent, the left-hand button. Then they wrote the misspellings. It should be noted that the comprehension task was easy because it was conducted only as a means of controlling the subjects' reading strategies.

Results and discussion

First, to test whether subjects' reading strategies were controlled, the subjects were divided into three eight-subjects groups depending on the means of response latencies as in Experiment 1. The mean latencies in each group were computed as a function of the position of a misspelling in a sentence. The results showed that the correlation coefficients were relatively high in all groups; in the faster group r=.81, in the medium group r=.82, and in the slower group r=.83. This showed that subjects in each group read stimuli from the beginning to the end in order. This showed that in Experiment 2 the subjects' reading strategies were successfully controlled by the comprehension task.

Correct detection. The seven stimuli were excluded from analysis as in Experiment 1. The mean detection rates were computed as a function of three conditions. The results are shown in Table 2. We conducted a three-way ANOVA including all three conditions, followed by separate analyses. Overall, the same pattern of results as in Experiment 1 was shown. The main effects of stimulus similarity, presentation unit, and display duration were significant [$F(1, 23)=151.2$, $p<.001$; $F(3, 69)=34.8$, $p<.001$; $F(2, 46)=128.4$, $p<.001$, respectively]. The interaction between presentation unit and display duration was also significant [$F(6, 138)=15.8$, $p<.001$].

The results of separate analyses were also similar to those in Experiment 1. In the 100-msec duration trials, both similar and dissimilar misspellings were detected more accurately in larger presentation units [$F(3, 23)=19.2$, $p<.001$; $F(3, 23)=44.5$, $p<.001$, respectively]. The fewest misspellings were detected in character presentations. In the 250-msec duration trials, no difference was shown between presentation units in both similar and dissimilar misspellings. In the 400-msec duration trials, misspellings in phrase presentations were detected more accurately than in character presentations [$F(3, 23)=3.5$, $p<.05$]. Moreover, more misspellings were detected in phrase presentations than in sentence presentations. This difference (15.6%) was larger than in Experiment 1 (7.6%) and marginally significant.

Two interesting effects were found for similar misspellings in the 400-msec duration trials. One was the facilitation effect, that is, misspelling detection in phrase presentations was facilitated compared with that in character presentations (19.7%). Proofreading is under constraints of context. Thus, the processing of constituent characters was facilitated by their word or lexical context in a phrase. The other was the disruption effect, that is, misspelling detection in sentence presentations was disrupted compared with that in phrase presentations (15.6%). For dissimilar misspellings in the 400-msec duration trials, on the other hand, no such effects were shown. The results for dissimilar misspellings were consistent with those of letter-detection in misspelled words in Healy et al. (1987). However, the results for similar misspellings were inconsistent.

From these findings, we made the following assumption about the search process in proofreading, based on the findings about letter-detection (Healy et al., 1987). First, even in proofreading, subjects read a sentence utilizing information about word shape instead of processing individual letters. When misspelled words were visually dissimilar to correctly spelled words, the subjects' attention was focused on constituent letters regardless of the presentation units. On the other hand, when the shape of misspelled words was the same as correctly spelled words, it would seem likely that misspelled words were skipped over without processing constituent letters. This happens often when a whole sentence is presented one at a time, because subjects tend to move on through a text for comprehension. When stimuli were presented in phrase or word presentations, subjects continue processing the display for the display duration. Therefore, the probability that the subjects' attention is focused on constituents and the misspellings are detected, is higher when stimuli were shown in phrase or word presentations for the long duration.

The effect of the comprehension task was analyzed in comparison with Experiment 1. The results showed that the means of detection rates were almost the same in both experiments [F(1, 46)=.04, p>.8]. Thus, it is considered that detection performance was not affected by the comprehension task.

Response latencies. The mean latencies of correct responses were computed. The results are shown in Table 2. We conducted a three-way ANOVA with all three conditions. The main effect of presentation units was significant [F(3, 69)=128.6, p<.001]. This result showed that subjects detected misspellings fastest in word and phrase presentations and slower in sentence presentations than in character presentations. The mean response latencies were almost the same as in Experiment 1. Whether or not the comprehension task was imposed made no difference [F(1,46)=.01, p>.9].

Comprehension task. Table 3 shows the mean percentages of the correct response for the comprehension task when misspellings were correctly detected. The correct response rates were generally high. This showed that subjects read stimuli for comprehension. We conducted a three-way ANOVA with all three conditions. The main effects of similarity, presentation unit, and display duration were statistically significant [F(1, 23)=13.6, p<.001; F(3, 69)=21.9, p<.001; F(2, 46)=16.8, p<.001, respectively]. The interactions between similarity and presentation unit and between presentation unit and display duration were also significant [F(3, 69)=11.0, p<.001; F(6, 138)=6.4, p<.001, respectively]. In the 100-msec duration trials and in character presentations, the correct response rates were low. Moreover, this was more likely to happen for similar misspellings. These results show that the correct response rates were low when misspelling detection was difficult.

General Discussion

The first aim of the present study was to investigate the processing units in proofreading. It was shown that the misspellings were detected more accurately in word and phrase presentations than in sentence and character presentations, when the display duration was sufficiently long. Moreover, neither the position of misspellings nor the number of characters in each presentation unit affected the latencies in word and phrase presentations. These findings suggest that words or phrases are processing units in the proofreading of Japanese sentences. The difference between word and phrase presentations is usually whether or not a content word is followed by a function word represented by a kana character in phrase presentations. Moreover, our experiments were limited to misspelling detection of content words. Therefore, more work is needed to clarify the difference between word and phrase presentations.

The results about processing units in proofreading are consistent with the unitization hypothesis (Drewnowski & Healy, 1977). The unitization hypothesis assumes that once a word is identified, the processing of its constituent letters stops, even if the letters have not yet been identified. When people read sentences, they move on through a text even if they do not identify the constituent letters. In this case, the processing of constituents is disrupted by the contexts. For example, Healy and her colleague (Healy, 1976, 1980; Healy & Drewnowski, 1983) found many more letter detection errors in correctly spelled words than in misspelled words. This phenomenon has been referred to as the "word inferiority effect". The disadvantage of sentence presentations in our study seems to reflect this disruption effect.

In other cases, however, word context facilitates the processing of constituents. For example, the "word superiority effect" was found in tachistoscopic experiments in which only one word was presented one at a time (Reicher, 1969). In that case, subjects would be likely to continue processing the constituents in a word even after it has been identified. Then, letter-level processing would be allowed to end normally and may in some cases be facilitated by word identification (Healy et al., 1987). In the present experiments, the advantage of words and phrases over characters reflected such facilitation effects. It is considered that semantic or lexical context facilitates both the processing of constituent characters and decision whether or not they were misspellings.

Comparing the processing of constituents in letter-detection in misspelled words with that in proofreading, it is possible that there are different processes in them. Healy et al. (1987) found no effects of display size on letter-detection in misspelled words. However, our proofreading experiments reported here showed clearly the effects of presentation units. It is suggested that when a target is predesignated, the subjects' attention is focused on the targets in misspelled words, which was not done when reading for meaning. On the other hand, in proofreading, in which no target is predesignated, subjects normally tend to read a sentence utilizing information from units larger than individual letters. It is considered that the processing in letter-detection in correctly spelled words and in proofreading involve some characteristics common to reading for meaning.

The second aim of the present study was to determine the effect of word-shape on proofreading by manipulating visual similarity. The detection rates for dissimilar misspellings were about 25% higher than that for similar misspellings. This large difference results from the wide range of visual similarity used in the present experiments. To detect similar misspellings, subjects need to focus their attention on the complex details of constituent characters. The result that similar misspellings were difficult to detect suggest that subjects would be likely to move on through a sentence utilizing information about word shape for proofreading, instead of information about the details of constituent characters.

The present experiments showed a strong effect of display duration, which reflects the fact that 'reading' rate depends a great deal upon what subjects are asked to do. In normal reading of English, reading rates range between between 200 and 350 words per minute (wpm). However, in letter-detection, the reading rate is as slow as 50 to 80 wpm (Rayner & Pollatsek, 1989). Though it is difficult to directly apply the findings in English to interpreting the results in Japanese, the reading rate in proofreading is assumed to be as slow as in letter-detection. In both 100-msec and 250-msec duration, the display duration seemed to be insufficient for processing in detail the constituent characters.

Recently, as word processors have become more wide spread, there are more chances for us to read or proofread sentences on a CRT display. The findings obtained in the present study may contribute to the construction of a system which helps proofreaders. The results of the present study suggest that if a function that presents Japanese sentences sequentially in words or phrases is added to word processors, the performance of proofreading on word processors would improve. More experiments are needed for examining these applied aspects.

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Appendix

Visual Similarity of Kanji characters

When stimulus characters were selected in this experiment, visual complexity between correct characters and misspelling characters was kept constant and their visual similarity was defined by whether the contour of the characters was similar or not. First, the difference in the number of strokes between a correct character and a misspelled character was limited to one. This is because large differences in the numbers of strokes yield a visual complexity difference. Second, stimulus type, as to whether a character pair was similar or not, was determined by the similarity of the peripheral directional contributivity feature (PDC feature) which is known in Japan as a useful feature for machine recognition (Hagita et al.,1983). All components of the PDC feature represent one of four directional run-lengths (horizontal, vertical, right diagonal, or left diagonal) extracted from every contour edge of a character. All similar character pairs have a high similarity in PCD features. Examples are shown in Figure 1.

Table 1

Percentage correct and response latencies (in Parentheses) for misspelling detection in Experiment 1

similarity type	duration (msec)	presentation unit			
		sentence	phrase	word	character
similar	100	65.2	45.0	26.0	18.5
		(3,015)	(1,655)	(1,436)	(2,676)
	250	67.1	65.6	62.0	51.5
		(3,366)	(1,772)	(1,878)	(1,889)
	400	67.9	75.5	75.0	69.4
		(3,616)	(1,769)	(1,6650	(2,139)
dissimilar	100	89.0	70.0	63.8	41.9
		(3,221)	(1,620)	(1,630)	(2,017)
	250	93.1	90.0	88.8	78.8
		(3,446)	(1,877)	(1,782)	(2,598)
	400	92.5	92.9	94.0	92.9
		(3,574)	(2,084)	(1,911)	(2,443)

Note. Response latencies are given in milliseconds.

Table 2

Percentage correct and response latencies (in Parentheses) for misspelling detection in Experiment 2

similarity type	duration (msec)	presentation unit			
		sentence	phrase	word	character
similar	100	55.3	43.3	36.0	11.0
		(3,246)	(2,120)	(1,851)	(1,743)
	250	68.3	67.7	67.6	57.6
		(3,465)	(1,853)	(1,825)	(1,753)
	400	66.9	82.5	74.7	62.8
		(3,216)	(1,812)	(1,556)	(1,965)
dissimilar	100	92.9	63.7	53.5	25.0
		(3,261)	(1,874)	(1,880)	(3,013)
	250	90.8	91.5	92.5	83.5
		(3,603)	(1,768)	(1,836)	(2,135)
	400	91.9	95.6	92.7	90.0
		(3,587)	(1,932)	(1,954)	(2,136)

Note. Response latencies are given in milliseconds.

Table 3

Percentage correct for the comprehension task in Experiment 2

similarity type	duration (msec)	presentation unit			
		sentence	phrase	word	character
similar	100	92.0	84.7	91.7	37.5
	250	92.6	90.2	94.3	77.4
	400	95.2	99.2	93.4	83.0
dissimilar	100	89.9	95.5	94.8	73.6
	250	95.6	99.0	96.7	98.1
	400	94.2	96.5	96.3	96.5

太郎は学校で気分が悪くなり、保健室へ
行ったところ、やはり微熱があった。

(a)

太犬　　窒室

微徴　　熱熱

(b)

Figure 1 (a) A typical Japanese sentences, and (b) examples of similar character pairs

Part 2 (Short Report)

Phonological and semantic processing in the proofreading of Japanese sentences

The objective of this study is to investigate which feature is utilized by proofreaders. We examined the role of phonological factor in Experiment 1, and semantic factor in Experiment 2.

Experiment 1

Method

Subjects. The subjects were twenty-four native Japanese adults. All subjects reported having normal or corrected-to-normal vision.

Apparatus. The same apparatus was used as in the experiments reported in Part 1.

Design. We used a three-way design with within-subject factors: phonological identity of stimuli (same-pronounced or different-pronounced), presentation unit (sentence, phrase, or word), and display duration (250 msec, or 400 msec per character). Two dependent variables were examined: detection rate and latencies for correct responses.

Materials. 240 simple Japanese sentences were constructed. Misspelled words were generated by using (1) incorrect but same-pronounced characters (i.e., same-pronounced misspellings), (2) incorrect but different-pronounced characters (i.e., different-pronounced misspellings). All of the misspelled characters are real Kanji characters, and the misspelled words are pronounceable nonwords. As for different-pronounced misspellings, no stimuli have the same pronunciation as real words. Figure 1 shows the examples of stimuli.

Procedure. General procedure is almost the same as the experiments reported in Part 1, except that the knowledge test for Kanji words was not conducted in this experiment.

Results and discussion

The results were shown in Figure 2 and Figure 3. Correct detection rates were generally high and no difference were shown between conditions. As for response latencies, same-pronounced misspellings were detected faster than different-pronounced misspellings ($p<.001$). Misspellings detection was faster for 250-msec duration than 400-msec duration ($p<.005$), and faster for word and phrase presentations than sentence presentations ($p<.001$).

These results show that phonological information did not affect the accuracy but affected the speed of misspelling detection. It is considered that phonological information is used in verification or response stage. Detected characters might be verified with the representations in lexicon, and be decided whether or not they are really misspellings. For same-pronounced misspellings, the representations to be verified can be retrieved easier than for different-pronounced misspellings by using phonological information.

Experiment 2

Method

Subjects. The subjects were sixteen native Japanese adults. All subjects reported having normal or corrected-to-normal vision.

Apparatus. Identical to that in Experiment 1.

Design. We used a three-way design with within-subject factors: lexicality of stimuli (word or nonword), presentation unit (sentence, phrase, word, or character), and display duration (250 msec, or 400 msec per character). Two dependent variables were examined: detection rate and latencies for correct responses.

Materials. 320 simple Japanese sentences were constructed. Misspelled words were generated by using (1) incorrect but real word (i.e., word misspellings), (2) incorrect but nonword (i.e., nonword misspellings). Figure 1 shows the examples of stimuli.

Procedure. General procedure was almost the same as that in Experiment 1, except each subject was tested in 320 trials in Experiment 2.

Results and discussion

The results are shown in Figure 4 and Figure 5. Detection rates were generally high. As for response latencies, nonword misspellings were detected faster than word misspellings ($p<.001$). Misspelling detection were faster for 250-msec duration than for 400-msec duration ($p<.001$), and more slowly for sentence presentations than for the other presentations ($p<.001$). These results show that lexicality of misspellings did not affect the accuracy but affected the speed of misspelling detection. It is considered that nonword misspellings can be detected at the moment word presentaions were shown. On the other hand, word misspellings can be detected only after some followed words or phrases were presented and the subjects processed their meaning.

Previous studies reported in Part 1 showed that visual similarity between correct characters and misspelled characters affected the accuracy but not affected the speed of the misspelling detection. On the contrary, phonological identity (Experiment 1) and lexicality (Experiment 2) of misspellings affected only the speed of misspelling detection.

太郎は、学校で気分が悪くなり、保健室へ行ったところ、やはり微熱があった。

（ａ）誤字無し試行

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（ｂ）類似誤字試行（Ｐａｒｔ１）

太郎は、学校で気分が悪くなり、保健室へ行ったところ、やはり美熱があった。

（ｃ）同音誤字試行（実験１）

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（ｄ）単語誤字試行（実験２）

Ｆｉｇｕｒｅ １　刺激例

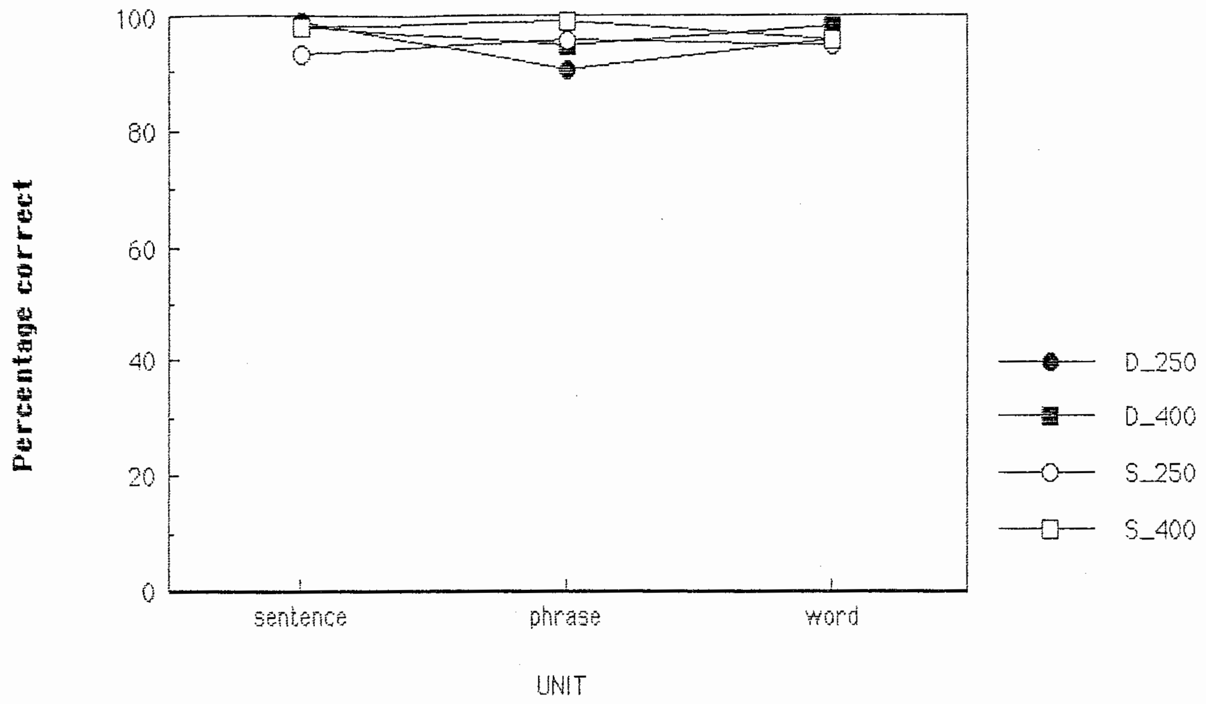

Figure 2 Percentage correct in Experiment 1

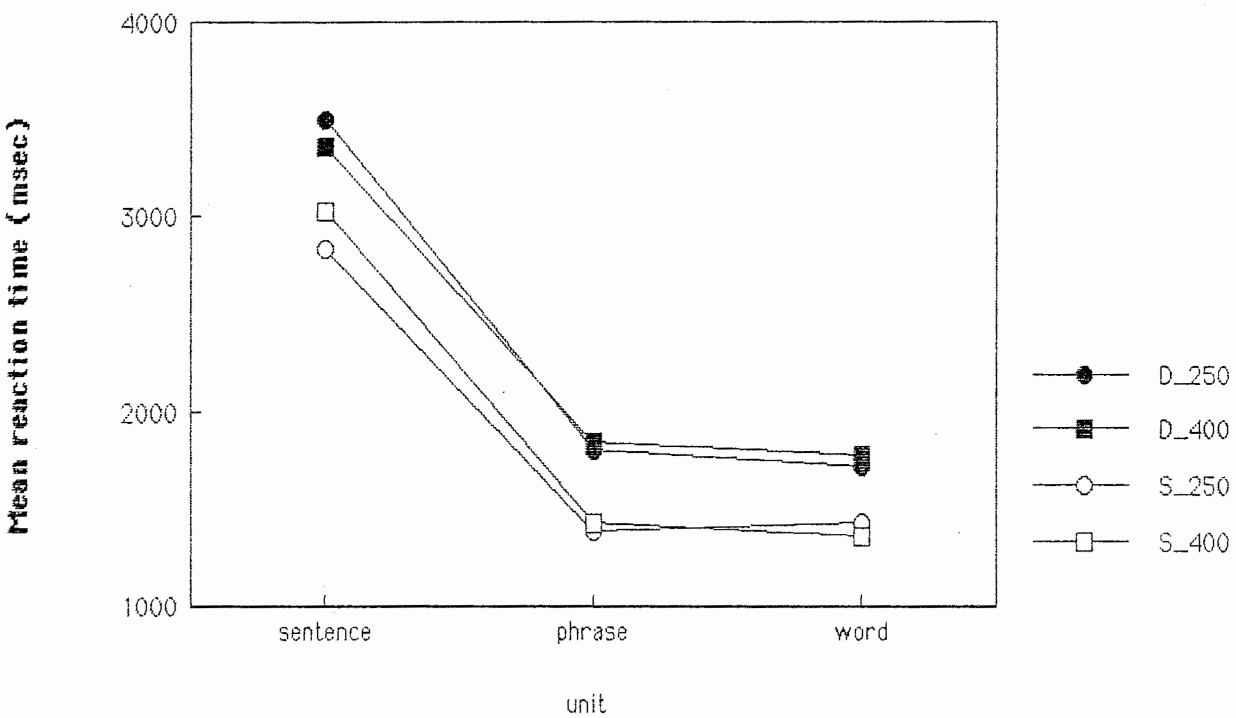

Figure 3 Response latencies in Experiment 1

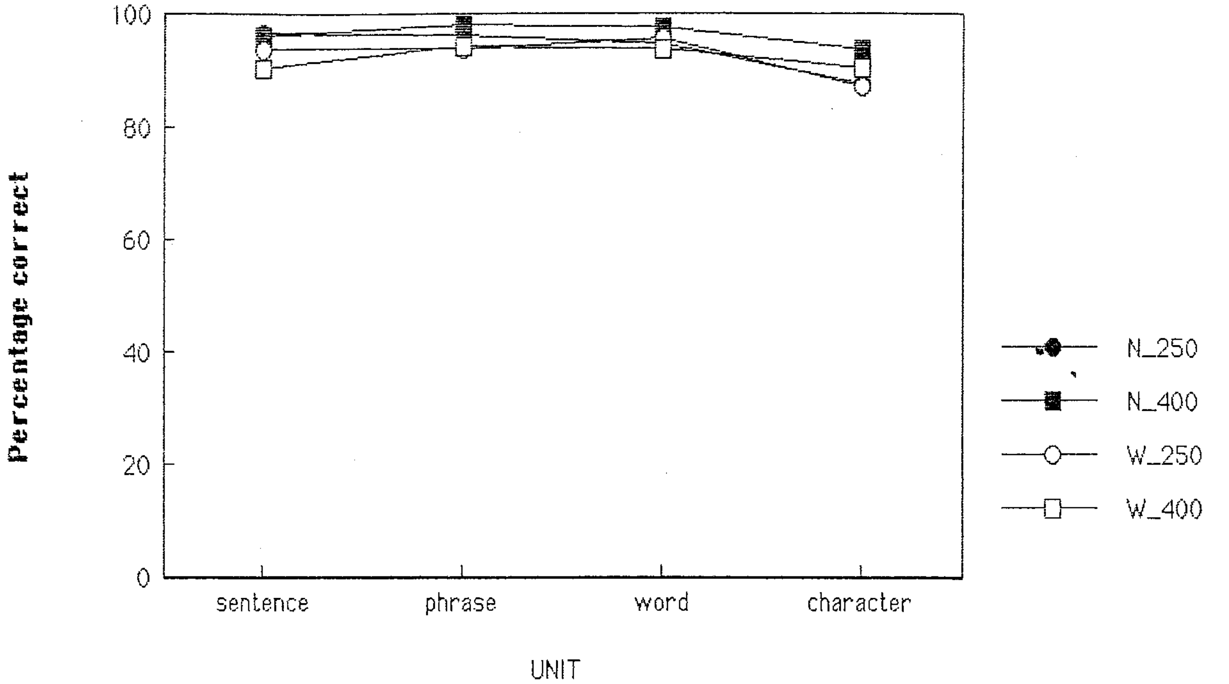

Figure 4 Percentage correct in Experiment 2

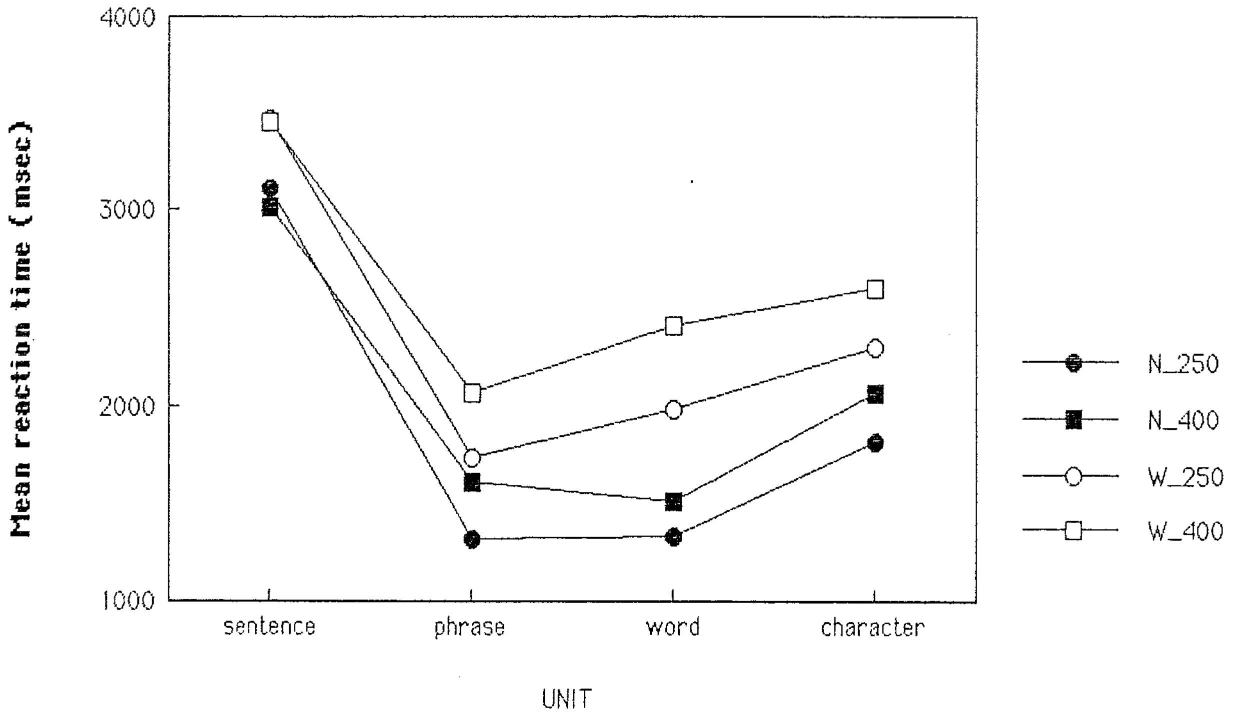

Figure 5 Response latencies in Experiment 2