The Effect of Visually and Phonologically Misleading Nonwords on Lexical Decisions of Native Japanese Readers

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Abstract

Native Japanese readers were found to rely heavily on visual codes and scarcely on phonological codes in letter/word processing (Mizuno, Matsui, & Bellezza, 2007). This study aimed to determine if this processing feature of native Japanese readers influenced their process of lexical access by lexical decision tasks using visually misleading transposed-letter (TL) nonwords, phonologically misleading pseudohomophones, and standard nonwords. Lupker and Pexman (2010) found that the performance on a lexical decision task of native English readers was impaired by both TL nonwords and pseudohomophones. However, the results of two experiments in this study showed that the performance of native Japanese readers was impaired not by pseudohomophones but by TL nonwords. The results suggested that the processing features of native readers of various languages should influence their process of lexical access.

Keywords: lexical decision; nonwords; transposed-letter; pseudohomophone; native Japanese readers; native English readers

Introduction

A lexical decision task (Meyer & Schvaneveldt, 1971) is a task in which participants decide whether presented letter strings are words or not. The lexical decision time of a word is considered to reflect the access time to lexical representation of the word, and the task has been used in many studies to explore the structure of lexical representation or the process of lexical access.

Various features of words have been found to influence lexical decision time. Such features include word frequency (e.g., Glanzer & Ehrenreich, 1979), neighborhood size [1] (Coltheart, Develaar, Jonasson, & Besner, 1977), semantic relation to primes (Neely, 1977), spelling-to-sound regularity (Parkin, 1982), and so on.

However, some research has shown that the effects of the features of nonwords on lexical decision time are also not negligible. For example, Shulman and Davidson (1977) found that pronounceable nonwords delayed the lexical decision time of words more than unpronounceable nonwords. Perea and Lupker (2004) found that the transposed-letter (TL) nonwords, which were made by transposing the two letters of words, delayed the lexical decision time for both words and nonwords. Lupker and Pexman (2011) compared the size of frequency effect in the TL, pseudohomophone, and standard nonword conditions. Frequency effect means that the lexical decision time of

more frequent words is shorter. They found that lexical decision time was longer and that frequency effect was greater in the TL and the pseudohomophone nonword conditions than in the standard nonword condition.

These findings about the effects of nonwords on lexical decision time not only contributed to the improved understanding of the process of lexical access but suggested that the features of nonwords should also be considered in using lexical decision tasks.

As described above, visually misleading TL nonwords and phonologically misleading pseudohomophones were confirmed to influence lexical decision time of words and nonwords. However, they were confirmed only with native English readers. Mizuno, Matsui, and Bellezza (2007) and Mizuno, Matsui, Harman, and Bellezza (2008) conducted several letter-matching experiments with native English and native Japanese readers, and found that native Japanese readers rely heavily on visual codes and not as much on phonological codes as native English readers do. Mizuno and Matsui (2012) also showed that visual similarity, rather than phonological similarity, between targets and distracters increased attentional blink of native Japanese readers, while Chun and Potter (1995) suggested that phonological similarity had a significant effect on the attentional blink of native English readers.

Consequently, we hypothesized that performance on a lexical decision task by native Japanese readers would not be impaired by phonologically misleading pseudohomophones because they rely scarcely on phonological codes. If this is verified, we will be able to not only indicate that their processing features of letters influence performance on lexical decision tasks but also alert many researchers using lexical decision tasks to take the processing features of their participants into account in choosing nonwords.

Experiment 1

Experiment 1 compared lexical decision time and error rates of native Japanese readers across the TL nonword condition, the pseudohomophone condition, and the standard nonword condition. We predicted that their lexical decision time would be delayed and error rates for nonwords would be high only in the TL condition, and not in the pseudohomophone condition and the standard condition.

Method

Participants and Design Thirty-six undergraduate students (14 women and 22 men) who were native Japanese

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[1] The number of words that can be created by changing one letter while maintaining letter positions.

readers participated in return for course credit. Participants were assigned to all three conditions: the TL nonword, the pseudohomophone, and the standard nonword conditions.

Equipment The experiment was conducted on a personal computer (Fujitsu, FMV Esprimo D5350) running an experimental software (Cedrus Co., SuperLab2.0) with a 17-in. liquid crystal monitor (EIZO, FlexScan S1731). Responses were collected by a response box (Cedrus Co., RB-730). A chin support (Takei, T.K.K. 123i with 123j) was placed on the edge of the desk. The distance between participants' eyes and the screen was about 45 cm, and the height of the chin support was adjusted for each participant.

Stimuli All the stimuli were two-character and four-mora *Kanji* words. In total, 120 words and 120 nonwords (40 TL nonwords, 40 pseudohomophones, and 40 standard nonwords) were selected/created in the following manner: 240 words of frequencies between 15,000 and 100,000 were selected from the database (Amano & Kondo, 2003); 40 TL nonwords were made by transposing two *Kanji* characters (e.g., "盟連", from "連盟"), confirming that they had no homophones; and the remaining 200 words were divided into five sets of 40 words each. Three sets were assigned to word sets, another set was used for making pseudohomophones, and another was used for making standard nonwords. Forty pseudohomophones were made by replacing each *Kanji* character with another *Kanji* character with the same phone (e.g., "案低", from "安定"). The 40 standard nonwords were created by exchanging one of the two *Kanji* characters with one of the other words (e.g.,"開税"), confirming that they were nonwords and had no homophones. The three nonword sets were combined with the three word sets to form six counterbalancing groups.

Japanese letters are typically written from left to right or from top to bottom but sometimes from right to left. The two letters, therefore, were written vertically from top to bottom lest the TL nonwords should be regarded as words. A two-letter stimulus presented on the monitor subtended 3 degrees of visual angles vertically and 1.5 degrees horizontally.

Procedure Six participants were allocated to each of the six counterbalancing groups. In each group, the orders of three nonword conditions were counterbalanced among the six participants.

Participants were tested individually. Each participant completed eight practice trials with standard nonwords followed by three blocks of 80 experimental trials. The order of the 80 trials was randomized. Participants were instructed to decide as quickly and accurately as possible whether the letter strings were a word or a nonword by pressing the right-most key if they were a word and the left-most key if they were not. In each trial, after a 1,100 ms interval, two asterisks written vertically were presented on the middle of the screen for 550 ms followed by the stimuli, which remained on the screen for three seconds or until the participant responded.

Results

Trials involving latencies greater than 1,500 ms (1.2% of the word trials and 3.2% of the nonword trials) were removed from the following analyses according to Lupker and Pexman (2010).

Word Lexical Decision Time Means of correct lexical decision time for words in the three nonword conditions are shown in Figure 1. One-way repeated measures analysis of variance (ANOVA) revealed that the effect of the nonword condition was significant, $F(2, 70) = 27.29$, $MSE = 5{,}528.08$, $p < .001$. Multiple comparisons showed that the mean lexical decision time in the TL condition was significantly longer than that in the pseudohomophone condition and the standard nonword condition, $ps < .01$, $HSD = 53.04$.

Word Error Rates Means and standard deviations of error rates for words in the three nonword conditions are shown in Table 1. ANOVA of arcsine transformed error rates revealed that the effect of the nonword condition was not significant, $F(2, 70) = 1.62$, $MSE = 37.97$, $p = .20$.

Nonword Lexical Decision Time Means of correct lexical decision time for nonwords in the three nonword conditions
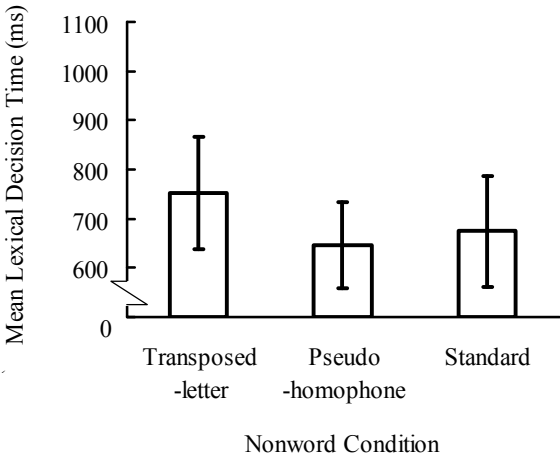

Figure 1: Mean and standard deviation of lexical decision time for words in each nonword condition in Experiment 1.

Table 1: Mean and standard deviation of error rates for words in each nonword condition in Experiment 1.

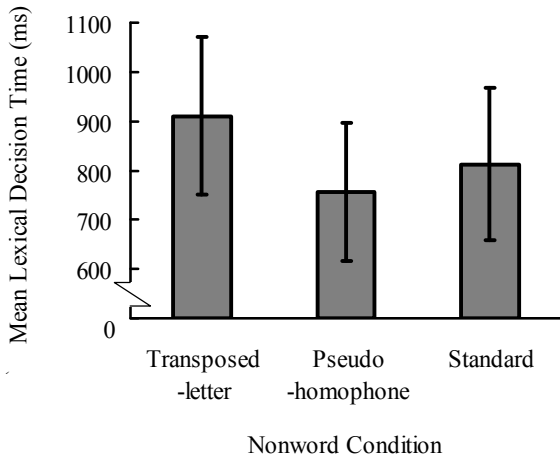|	Nonword Condition		
	Transposed-letter	Pseudo-homophone	Standard
Mean	0.061	0.048	0.060
SD	0.043	0.039	0.037

Figure 2: Mean and standard deviation of lexical decision time for nonwords in each nonword condition in Experiment 1.

Table 2: Mean and standard deviation of error rates for nonwords in each nonword condition in Experiment 1.

| | Nonword Condition | | |
	Transposed -letter	Pseudo -homophones	Standard
Mean	0.097	0.042	0.060
SD	0.044	0.034	0.032

are shown in Figure 2. ANOVA revealed that the effect of the nonword condition was significant, $F (2, 70) = 29.86$, $MSE = 13,857.37$, $p < .001$. Multiple comparisons showed that the mean lexical decision time in the TL condition was significantly longer than that in the pseudohomophone condition and the standard nonword condition, $ps < .01$, $HSD = 83.97$, and that the time in the pseudohomophone condition was shorter than that in the standard nonword condition, $p < .05$, $HSD = 66.71$.

Nonword Error Rates Means and standard deviations of error rates for nonwords in the three nonword conditions are shown in Table 2. ANOVA of arcsine transformed error rates showed that the effect of the nonword condition was significant, $F (2, 70) = 19.98$, $MSE = 26.92$, $p < .001$. Multiple comparisons revealed that the error rate in the TL nonword condition was higher than that in the pseudohomophone condition and the standard nonword condition, $ps < .01$, $HSD = 3.70$, and that in the pseudohomophone condition was lower than that in the standard nonword condition, $p < .05$, $HSD = 2.94$.

Discussion

The lexical decision time for words in the TL condition was longer than the lexical decision times for words in the pseudohomophone condition and in the standard condition.

This result was different from that of Lupker and Pexman (2010) with native English readers, which showed that lexical decision times for words in the TL condition and pseudohomophone condition were longer than the corresponding time in the standard nonword condition. This result suggests that lexical decision time for words of native Japanese readers, who do not rely so much on phonological codes, is not delayed by phonologically misleading nonwords. Error rates for words did not differ among nonword conditions, consistent with the result of Lupker and Pexman (2010).

As for nonwords, the results showed that lexical decision time in the TL condition was longer than in the other two conditions, and that error rates in the TL condition were higher than those in the other two conditions. However, Lupker and Pexman (2010) with native English readers showed that their lexical decision times and error rates in the TL and pseudohomophone conditions were greater than those in the standard nonword condition. These results indicated that the effect of phonologically misleading nonwords was scarce in the case of native Japanese readers.

Nonetheless, we did not expect that the lexical decision time in the pseudohomophone condition would be shorter than that in the standard nonword condition, or that the error rate in the pseudohomophone condition would be lower than that in the standard nonword condition. These results were inconsistent with the previously mentioned results indicating that phonological codes have a scarce effect on lexical decisions of native Japanese readers, and we considered it implausible to suppose that the phonological codes of pseudohomophones made lexical decision of nonwords easy.

Therefore, we reexamined the frequencies and stroke counts of all *Kanji* characters consisting of the nonwords in the three conditions. The stroke counts of *Kanji* characters (see Table 3) reflect their visual complexities. The means of frequencies and stroke counts (with standard deviations in parentheses) were, respectively, 456,281.6 (566,312.9) and 9.775 (4.40) for TL nonwords, 305,685.2 (392,268.0) and 8.91 (3.24) for pseudohomophones, and 497,443.0 (515,634.1) and 9.56 (3.73) for standard nonwords. The mean frequency and the mean stroke count of pseudohomophones were smaller than the others. A low frequency was likely to increase both lexical decision time and error rate. It could not unexpectedly decrease lexical decision time, or the error rate in the pseudohomophone condition. Therefore, we concluded that the low stroke counts were the real cause. Because native Japanese speakers tend to rely heavily on visual codes, it was

Table 3: Examples of stroke counts.

Stroke Count		
3	8	13
大	性	新

extremely plausible that the small mean of stroke counts of pseudohomophones made lexical decision time shorter and error rates lower than those of standard nonwords.

In Experiment 2, therefore, some of the *Kanji* characters consisting of pseudohomophones and standard nonwords were substituted so as to make the means of stroke counts and those of frequencies as even as possible in the three nonword conditions.

Experiment 2

Method

Participants and Design Thirty-six undergraduate students (13 women and 23 men) who were native Japanese readers participated in return for course credit. Participants were assigned to all three conditions: the TL nonword, the pseudohomophone, and the standard nonword conditions.

Stimuli The 120 words and 40 nonwords in the TL conditions were the same as those used in Experiment 1. Some of the *Kanji* characters in the pseudohomophone condition and the standard nonword condition used in Experiment 1 were substituted with other *Kanji* characters to make the means of stroke counts, along with the frequency of *Kanji* characters composing the nonwords, in the three conditions as equal as possible. The resultant means (with standard deviations in parentheses) of stroke counts and frequency of *Kanji* characters composing the nonwords in the TL condition were 9.78 (4.40) and 456,281.6 (566,312.9), respectively, those in the pseudohomophone condition were 9.76 (3.52) and 412,652.3 (369,488.1), and those in the standard nonword condition were 9.78 (3.72) and 422,790.2 (454,322.7).

Equipment and Procedure These were the same as in Experiment 1.

Results

Trials involving latencies greater than 1,500 ms (2.9% of the word trials and 6.7% of the nonword trials) were removed from the following analyses as in Experiment 1.

Word Lexical Decision Time Means of correct lexical decision time for words in the three nonword conditions are shown in Figure 3. One-way repeated measures ANOVA revealed that the effect of nonword condition was significant, $F(2, 70) = 12.47$, $MSE = 5,572.14$, $p < .001$. Multiple comparisons showed that the mean lexical decision time in the TL condition was significantly longer than that in the pseudohomophone condition and the standard nonword condition, ps < .01, $HSD = 53.25$.

Word Error Rates Means and standard deviations of error rates for words in the three nonword conditions are shown in Table 4. ANOVA of arcsine transformed error rates revealed that the effect of the nonword condition was not significant, $F(2, 70) = 0.32$, $MSE = 48.80$, $p = .73$.
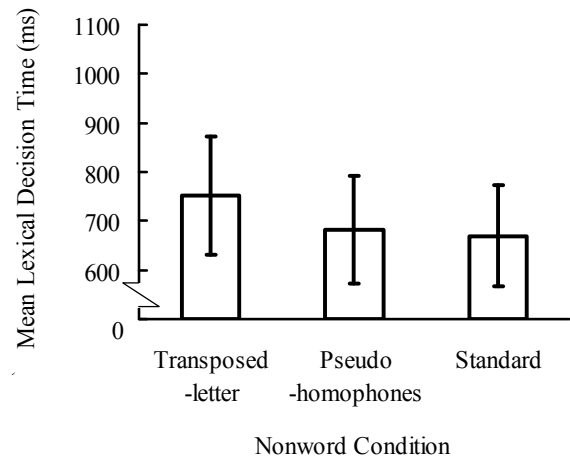

Figure 3: Mean and standard deviation of lexical decision time for words in each nonword condition in Experiment 2.

Table 4: Mean and standard deviation of error rates for words in each nonword condition in Experiment 2.

	Nonword Condition		
	Transposed -letter	Pseudo -homophone	Standard
Mean	0.051	0.059	0.048
SD	0.044	0.049	0.038

Nonword Lexical Decision Time Means of correct lexical decision time for nonwords in the three nonword conditions are shown in Figure 4. ANOVA revealed that the effect of the nonword condition was significant, $F(2, 70) = 16.55$, $MSE = 9,425.45$, $p < .001$. Multiple comparisons showed that the mean lexical decision time in the TL condition was significantly longer than that in the pseudohomophone condition and the standard nonword condition, ps < .01, $HSD = 69.25$.

Nonword Error Rates Means and standard deviations of error rates for nonwords in the three nonword conditions are shown in Table 5. ANOVA of arcsine transformed error rates showed that the effect of nonword condition was significant, $F(2, 70) = 5.36$, $MSE = 32.03$, $p = .007$. Multiple comparisons revealed that the error rate in the TL nonword condition was higher than that in the pseudohomophone condition and the standard nonword condition, ps < .05, $HSD = 3.21$, and no difference was found between the latter two conditions.

Discussion

As expected, the lexical decision time for words in the TL nonword condition was longer than that in the pseudohomophone condition and the standard condition, and there was no difference between the latter two conditions.
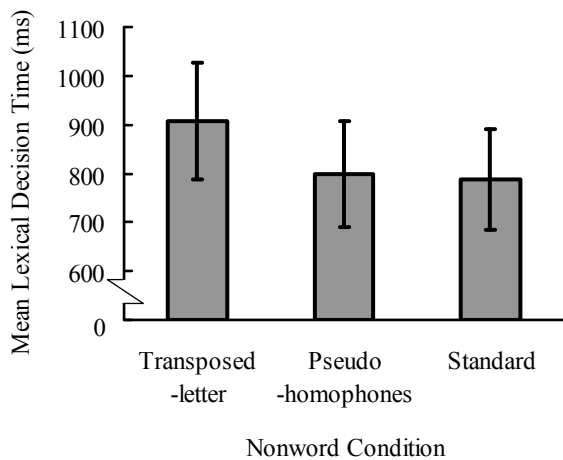
Figure 4: Mean and standard deviation of lexical decision time for nonwords in each nonword condition in Experiment 2.

Table 5: Mean and standard deviation of error rates for nonwords in each nonword condition in Experiment 2.

	Nonword Condition		
	Transposed -letter	Pseudo -homophones	Standard
Mean	0.101	0.064	0.068
SD	0.055	0.036	0.050

This result suggests that phonologically misleading nonwords have no effect on the lexical decisions of native Japanese readers. The error rates for words did not differ between the three nonword conditions, which is with the results of Lupker & Pexman (2010) with native English readers.

The lexical decision time for nonwords was the longest in the TL nonword condition, and there was no difference between that in the pseudohomophone condition and that in the standard nonword condition. This result was also expected and indicates that native Japanese readers rely scarcely on phonological codes. The error rate for words in the TL condition was higher than that in the standard nonword condition, and no other difference was found. Lupker and Pexman (2010) found that error rates in both the TL condition and the pseudohomophone condition were higher than the error rate in the standard nonword condition with native English readers. This result, therefore, suggests that native Japanese readers make fewer errors when deciding if phonologically misleading nonwords are nonwords because they scarcely rely on phonological codes.

General Discussion

In Experiment 1, the lexical decision times for words and for nonwords were shorter and the error rate for nonwords was lower in the pseudohomophone condition than those in the TL nonword condition. These results suggested that the processing feature of native Japanese readers relying heavily on visual codes and scarcely on phonological codes had influenced their performance on lexical decision tasks. However, it was inconsistent with their processing feature that the lexical decision time for nonwords was shorter and the error rate for nonwords was lower in the pseudo-homophone condition than those in the standard nonword condition. This was considered due to the stroke counts reflecting the visual complexity of *Kanji* characters consisting of pseudohomophones more than those consisting of TL nonwords and standard nonwords used in Experiment 1.

In Experiment 2, the experiment was replicated after making the means of the stroke counts of *Kanji* characters consisting of nonwords in the three conditions as equal as possible. Consequently, lexical decision time was longer and error rate was higher in the TL conditions than those in the pseudohomophone condition and the standard nonword condition, and no difference was found between the latter two conditions. These results indicated that native Japanese readers rely scarcely on phonological codes but rely heavily on visual codes.

These results, in general terms, serve as evidence that processing characteristics of native readers of a certain language could influence performance on the lexical decision task. We hope that this will be a warning to all researchers who use this task.

We finally discuss the process of lexical decision of native Japanese readers in terms of some models of lexical access. According to Shimomura and Goryo (1998), the models of lexical access are roughly divided into two categories: single-route models and dual-route models. Single-route models suppose that phonological information processing always mediates lexical access (e.g., Van Orden, 1987). Dual-route models suppose that visual information processing and phonological information processing proceed in parallel (e.g., Coltheart, 1978), and some models also suppose that the two routes interact with each other (e.g., Ferrand & Grainger, 1994).

The results of this study indicated that phonologically misleading pseudohomophones had no effect on the performance of lexical decision tasks by native Japanese readers. They indicate that phonology does not necessarily mediate lexical access; this finding contradicts the single-route model, which supposes phonological mediation. At the same time, the results of this study contradict the dual-route model as well—the very reason Coltheart (1978) proposed a dual-route model was that pseudohomophones delayed the lexical decision time of native English readers.

However, a few recent studies support the validity of the dual-route model. Grainger, Muneaux, Farioli, and Ziegler (2005) examined the effect of visual and phonological neighborhood density on lexical decision time. They found that lexical decision time was short when both visual neighborhood and phonological neighborhood were dense or sparse because the target lexicon was likely to be the same, namely, because the cross-code consistency was high.

They also found that lexical decision time was prolonged when only one of the neighborhoods was dense because the target lexicon was likely to be different, namely, because cross-code consistency was low. They asserted that these results support the dual-route model, and these results were also found by Hino, Nakayama, Miyamura, and Kusunose (2011) with native Japanese participants.

We, therefore, felt that the results of this study should be explained by a dual-route model. We also considered that it is basically implausible to suppose that the processes of lexical access are disparate among native readers of different languages. How, then, could the results with native English readers and those with native Japanese readers be explained by the same dual-route model?

The Japanese language features an unparalleled number of homophones. This situation is similar to the situation when phonological neighborhood is dense and visual neighborhood is sparse—the cross-code consistency being very low. Native Japanese readers do know that the use of both visual and phonological codes, especially of phonological codes, delays their lexical access. Accordingly, they choose to rely heavily on visual codes and scarcely on phonological codes. On the other hand, the English language does not have as many homophones, and the cross-code consistency is high. Native English readers know the situation and do not reduce their reliance on phonological codes. Therefore, the use of pseudohomophones impaired their performance on lexical decision tasks. In brief, we believe that the results of this study are inconsistent with those of Coltheart et al. (1977) because the phonological processing features of native Japanese readers differ from those of native English readers, although their processes of lexical access are basically similar.

Human information processing must be highly efficient; it is unconceivable that people adhere to inefficient processing. We consider that it is most natural and reasonable to suppose that people change flexibly the weights of visual and phonological processing according to the features of their languages or situations, realizing the most efficient lexical access.

References

Amano, N., & Kondo, K. (2003). *NTT database series: Lexical properties of Japanese. Vol. 2. CD-ROM Version.* Tokyo: Sanseido.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing*. New York: Academic Press.

Coltheart, M., Develaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI*. Hillsdale, NJ: Erlbaum.

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 109-127.

Ferrand, L., & Grainger, J. (1994). Effects of orthography are independent of phonology in masked form priming. *Quarterly Journal of Experimental Psychology, 47A(2)*, 365-382.

Glanzer, M., & Ehrenreich, S. L. (1979). Structure and search of the internal lexicon. *Journal of Verbal Learning and Verbal Behavior, 18*, 381-398.

Grainger, J., Muneaux, M., Farioli, F., & Ziegler, J. C. (2005). Effects of phonological and orthographic neighborhood density interact in visual word recognition. *Quarterly Journal of Experimental Psychology, 58A*, 981-998.

Hino, Y., Nakayama, M., Miyamura, S., & Kusunose, Y. (2011). Orthographic and phonological neighborhood size effects for Japanese Katakana words in a lexical decision task. *Japanese Journal of Psychology, 81*, 569-576.

Lupker, S. J., & Pexman, P. M. (2010). Making things difficult in lexical decision: The impact of pseudohomophones and transposed-letter nonwords on frequency and semantic priming effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 1267-1289.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words; Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227-234.

Mizuno, R., & Matsui, T. (2012). Difference due to native language in the determinant of target-distracter discriminabiliy influencing attentional blink. *Tokai Journal of Psychology, 6*, 1-10.

Mizuno, R., Matsui, T., & Bellezza, F. S. (2007). Difference between native English and native Japanese readers in the use of visual and phonological codes in processing phonograms. *Japanese Journal of Cognitive Psychology, 5*, 1-10.

Mizuno, R., Matsui, T., Harman, J. L., & Bellezza, F. S. (2008). Encoding times of phonograms by English and Japanese readers: Eliminating the time for attention switching. *Japanese Journal of Cognitive Psychology, 5*, 93-105.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited capacity attention. *Journal of Experimental Psychology: General, 106*, 226-254.

Parkin, A. J. (1982). Phonological recoding in lexical decision: Effects of spelling-to-sound regularity depend on how regularity is defined. *Memory & Cognition, 10*, 42-53.

Perea, M., & Lupker, S. J. (2004). Can CANISO prime CASINO? Transposed letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language, 51*, 231-246.

Shimomura, M., & Goryo, K. (1998). Shinteki jisyo gainen kara mita tango ninchi no mondai [The problems of word recognition in terms of lexicon]. In N. Osaka (Ed.), *Yomi: Nou to kokoro no jouhou shori* [Reading: Information processing in brain and mind]. Tokyo: Asakura.

Shulman, H. G., & Davidson, T. C. B. (1977). Control properties of semantic coding in a lexical decision task. *Journal of Verbal Learning and Verbal Behavior, 16*, 91-98.

Van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory & Cognition, 15*, 191-198.