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EFFECTS OF VOCAL INTERFERENCE ON IDENTIFYING KANJI, HIRAGANA AND KATAKANA WORDS BY SKILLED AND LESS SKILLED JAPANESE READERS IN GRADES 4–6

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The two experiments in the study involving 108 grades 4, 5, and 6 Japanese children divided into skilled and less skilled readers examined the effects of vocal interference on the lexical decisions of target words written in two scripts (kanji and hiragana in Experiment 1, and katakana and hiragana in Experiment 2) presented in the same sentence contexts. While the processing of both the kanji and kana scripts were adversely affected by vocal interference, younger children and less skilled readers were more impeded than the older children and the skilled readers. Some suggestions are made about the factors affecting phonetic recoding in the morphemic kanji script, at least some of the times, and the regular kana script, under certain conditions.

Japanese orthography contains both phonetic (kana) and morphemic (kanji) scripts, which are used interdependently to represent Japanese utterances. Kana has two sets of syllabic symbols: hiragana is mostly used for grammatical inflexions, and katakana is for writing alphabetic loanwords. Kanji is originally derived from Chinese characters which contains phonetic components in addition to semantic elements. Linguistic descriptions (Anderson, 1987; Gelb, 1964; Sampson, 1985) of these two scripts usually suggest that kanji is a logographic script with direct access to the lexicon, and kana is a syllabic script with indirect access to the lexicon. There are similar claims in the psychological literature (Goryo, 1987; Saito, 1981, 1982). However, some kana words, at least high frequency katakana words, could be processed without necessary reference to phonology (Besner & Hildebrandt, 1987). Conversely, processing of the cognate Chinese script may involve phonetic recoding some of the times at the working memory stage (Hung & Tzeng, 1981; Leong, 1986, 1987; Tzeng, Hung & Wang, 1977).

To test the notion of visual-phonetic processing of kanji and semantic processing of kana as suggested by Morton and Sasanuma (1984), Kimura (1984) carried out a study using kanji and hiragana words and with concurrent vocal interference (repeating the numbers 1 to 5). She found the vocal interference had no effect on kanji processing, but interrupted hiragana processing. She interpreted the results to mean vocal articulation disturbed prelexical phonological coding in kana. Her statement seems too strong. She overlooked other factors influencing lexical access such as script familiarity, word frequency and homophonic effects. However, her

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study using vocal interference suggests an effective way to study its effect on phonetic recoding at the syllabic or oral level of the Japanese kanji.

There are suggestions that writing systems differ in the degrees of direct (lexical) or indirect (phonological) processing at the perceptual level, but not so much at the comprehension level. Besner (1987), for example, suggested that "while linguistic descriptions of alphabetic English and Japanese kana are quite different, the psychological processes involved in their oral reading have more in common than previously thought" (p. 217). The present study was carried out in order to clarify some of the issues in the information processing of kanji and kana in the Japanese orthography. Specifically the two experiments, one involving kanji and hiragana words and the other katakana and hiragana words, attempted to define at the way in which vocal interference may affect the visual-phonetic processing of kanji and phonetic recoding of kana as these scripts are processed by grades 4, 5, and 6 Japanese children dichotomized as skilled and less skilled readers.

Experiment 1

Lexical decisions were conducted under two script conditions for the target words: (a) commonly-used content words almost always written in kanji characters, and (b) the same content words written in hiragana. Each word (target word) was presented as part of a short sentence and subjects were asked to decide accurately and rapidly whether or not the target word belonged to a certain semantic category, such as items of sport or clothing. The basic assumption was that the target kanji words written in hiragana would require the use of phonetic recoding to access the lexicon, whereas commonly used kanji words written in kanji would be processed via the direct lexical route. However, in processing lexical items (words) in sentence contexts, it is necessary to recode the items phonetically for ease of storage in working memory needed in processing strings of words. Therefore, sentence contexts may require operation of phonetic recoding, or even accommodate some extra cues for lexical decisions which may minimize the degree of phonetic involvement. Using a concurrent task condition of vocal interference, the main question asked in this experiment was whether commonly-used kanji words printed in hiragana required phonetic recoding, and whether commonly-used kanji words printed in kanji characters were mainly processed directly to access the lexicon.

Method

Subjects: The 108 students for the study were selected from a larger pool of 200 subjects from a medium-sized elementary school in Osaka, Japan. There were 36 subjects in each of grades 4, 5 and 6 with an equal number of male and female students. The mean chronological ages for the three grades were respectively 124.25, 137.92 and 149.42 months with standard deviations of 4.03, 3.11 and 3.26 months respectively. The means with standard deviations on the TK Reading Ability Test scores (Kitao, 1984) for the grades 4, 5 and 6 groups of 36 children each were respectively 84.58 (12.77), 106.50 (38.55), and 118.07 (39.17). The 36 children in each grade were dichotomized into skilled and less skilled readers on the basis of the TK Reading Ability Test.

Stimulus Items: Experiment 1 was designed to use target words normally written with two kanji characters to clarify the procedures of kana and kanji lexical access. The 10 target words selected from the frequency list of Ogawa (1972) were presented either as composite two kanji characters or as the same sounding words written in hiragana. The same target word-pairs differing in the script forms of typically used kanji or hiragana were embedded in the same short sentence frame to show the semantic category of the words. For example, the target word "baseball" embedded in the short sentence of "*Baseball* is a sport." was presented in two scripts: 野球はスポーツです。(target in kanji) and やきゅうはスポーツです。(target in hiragana). There were 10 target words in semantically correct sentences and 10 equivalent words in hiragana also embedded in the same 10 sentence frames. Two sets of 10 pairs of corresponding target words in kanji and hiragana constructed by making a slight change in one of the kanji characters and the changed word presented in the hiragana symbols. Both sets of 10 pairs embedded in the same sentence frame as the semantically correct sentences were used as foils or controls. For example, for the previous semantically correct sentence of "*Baseball* is a sport.", the parallel semantically incorrect sentences were "The globe is a sport." 地球はスポーツです。(target word in kanji), and ちきゅうはスポーツです。(target word in hiragana). The corresponding 20 semantically incorrect sentences embedding ten pairs of the slightly different target words are also written in the usual kanji script or the less familiar hiragana script.

Procedure: The 108 grades 4 to 6 students were tested individually in a quiet room at their school. They were asked to decide accurately and rapidly if the target words embedded in short sentence shown on the microcomputer screen belonged to particular semantic categories as shown in the sentence frames (i.e., whether the sentences made sense), and were given appropriate feedbacks. The 20 sets of semantically correct sentences with the 10 equivalent target words written in kanji and hiragana respectively, and the 20 sets of semantically incorrect control sentences also with 10 equivalent target words written in kanji and hiragana respectively were presented at random. The subjects were randomized into subgroups with one half taking the vocal interference condition first followed by the no-interference condition in about 30 days' time and the other half reversing the conditions. For the vocal interference condition, subjects were asked to count repeatedly in Japanese the numbers one to ten while they were making the semantic decisions. For all conditions, subjects responded by pressing a YES key (e.g., "*Baseball* is a sport") or a NO key (e.g., "*The globe* is a sport"). The responses provided both accuracy and reaction time (RT) measures for subsequent statistical analyses.

Results

The 40 RT measures for each child was edited for outliers with 2.5 standard deviations above or below the mean RT used as the upper or lower limits. The

Table 1. Means and Standard Deviations (in Parentheses) for Reaction Time of Lexical Decisions by Grade, Reading Level, Script and Vocal Interference (VI)

Grade	Reading Level	Semantically Correct Sentence				Semantically Incorrect Sentence			
		Without VI		With VI		Without VI		With VI	
		Kanji	Hiragana	Kanji	Hiragana	Kanji	Hiragana	Kanji	Hiragana
4	Skilled	1366 (333)	1329 (348)	1318 (308)	1331 (295)	1602 (378)	1552 (391)	1616 (429)	1484 (369)
	Less Skilled	1574 (456)	1624 (509)	1775 (348)	1745 (372)	1740 (524)	1699 (514)	1933 (430)	1934 (490)
5	Skilled	1100 (248)	1153 (273)	1157 (330)	1155 (338)	1401 (403)	1350 (399)	1336 (481)	1317 (404)
	Less Skilled	1542 (362)	1617 (416)	1675 (288)	1786 (456)	1803 (385)	1892 (408)	1947 (325)	2014 (339)
6	Skilled	1006 (238)	1051 (279)	1005 (293)	1035 (265)	1259 (279)	1200 (277)	1185 (327)	1214 (365)
	Less Skilled	1225 (302)	1262 (310)	1358 (354)	1463 (331)	1461 (332)	1514 (351)	1587 (322)	1629 (434)

Note: VI refers to vocal interference.

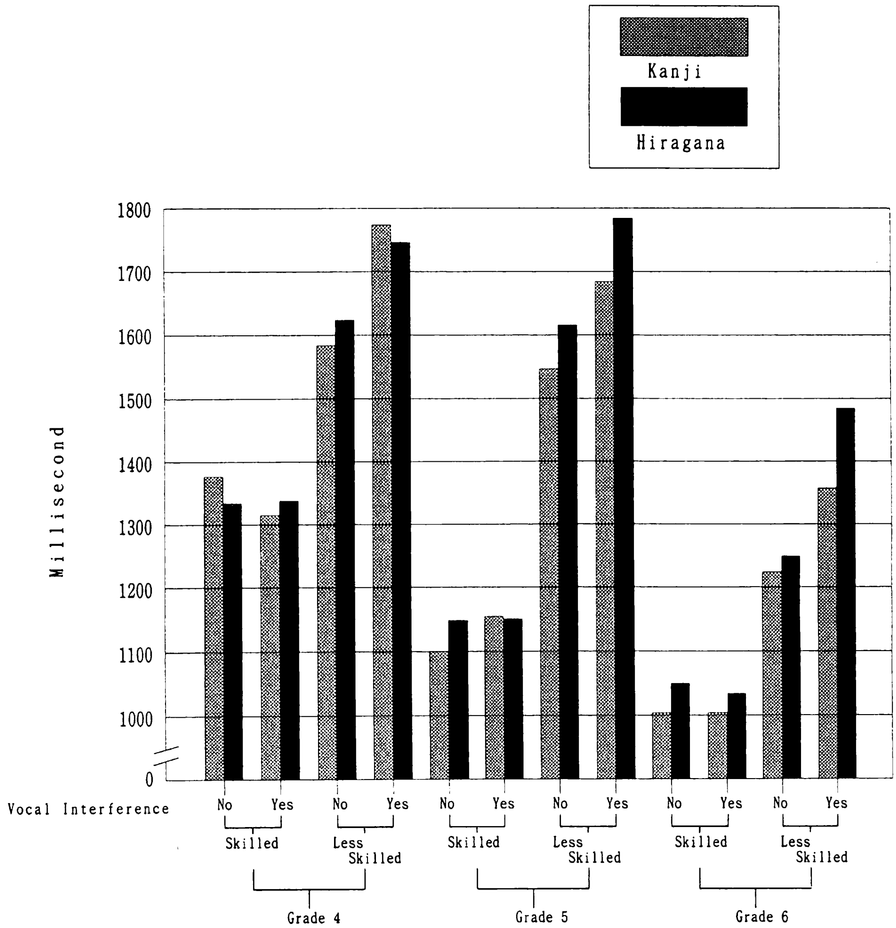

Fig. 1. Mean reaction time of processing target kanji and hiragana words in semantically correct sentences by grade, reading level, and articulation condition.

overall mean accuracy rate for the 3 grades with and without vocal interference in the lexical decisions of both semantically correct and incorrect sentences were respectively 78.91% (10.93%) and 78.45% (11.38%). An initial 3(grade) × 2(reading level) × 2(meaningfulness) ANOVA with the last factor repeated using correct edited RT scores shows the expected faster processing of semantically correct sentences over semantically incorrect ones (F (1, 102) = 161.97, $p < .0001$), and no interaction effects. Since the semantically incorrect sentences were used as controls and were not direct interest, further statistical analyses were carried out only with the correct RT scores of the semantic correct sentences.

The main analyses examined the effects of vocal interference on the processing of target kanji and equivalent hiragana words in relation to grade and reading levels. In a 3(grade) × 2(reading level) × 2(vocal articulation) × 2(script) ANOVA with the last two factors repeated, the main effects for grade, reading level, vocal interference, and script were all highly significant in the expected direction: (F (2, 102)=14.92, p<.0001, F (1, 102)=58.48, p<.0001, F (1, 102)=4.56 p<.05, F (1, 102)=8.42, p<.01 respectively). For the last-named, the mean processing time for those semantically correct sentences with target words in kanji was 1342 msec. and for the same semantically correct sentences with equivalent hiragana words was 1379 msec. There was also a significant reading level × vocal interference effect (F (1, 102)=4.68, p<.05). These results are summarized in Table 1 and Fig. 1.

Collapsing across grades and reading levels, the mean RT increase as a result of vocal interference compared with the no interference condition in the lexical decision of the target words in kanji was 475 msec. and of the target words in hiragana was 479 msec. Thus, the relative interference effect with the two scripts was about the same. In separate analyses and collapsing across grades, the overall mean effect sizes for the skilled readers were negligible for both scripts, but for the less skilled readers they were of the magnitude of 155.7 msec. for target words in kanji and 163.7 msec. for target words in hiragana. It would thus appear that vocal interference affected less skilled readers more than skilled ones. Vocal interference also retained the processing of the scripts by the younger children more than the older ones.

Experiment 2

Lexical decisions of katakana word classifications were conducted under two script conditions: (a) commonly-used content katakana words almost always written in katakana, and (b) the same content katakana words written in hiragana. As with Experiment 1, each word (target word) was presented as part of a short sentence and subjects were asked to decide accurately and rapidly whether or not the target word belonged to a certain semantic category. It was assumed that, in processing lexical items (words) in a short sentence (semantic contexts), it is necessary to recode the items phonetically for ease of storage in working memory needed in processing strings of words. Therefore, using a concurrent task condition of vocal interference, the main question asked in Experiment 2 was whether katakana words printed in hiragana required a higher degree of phonetic recoding than the same words printed in katakana for lexical decisions. If so, the hiragana words would be more affected by vocal interference.

Method

Subjects: The same 108 students in Grades 4 to 6 served as subjects for Experiment 2.

Stimuli: Experiment 2 was designed to use target words normally written in katakana in order to clarify the procedures of katakana and hiragana lexical access for semantic judgments when script unfamiliarity is present. The target words selected the frequency list of Ogawa (1972) were presented in either of the two script conditions: (a) 10 katakana words printed in katakana, or (b) 10 katakana words printed in hiragana. The same target word-pairs differing in the script forms of typically used katakana or hiragana were embedded in the same short sentence frame to show the semantic category of the words. For example, the target katakana word, "organ" embedded in the short sentence of "*An organ* is an musical instrument.") was presented in two scripts: オルガンは楽器です。(target in katakana) and おるがんは楽器です。(target in hiragana). There were altogether 20 semantically correct sentences: 10 sentences with 10 target words presented in katakana, and the same 10 sentences with 10 equivalent target words presented in hiragana. Two sets of 10 pairs of corresponding target words in katakana and hiragana chosen from the commonly-used katakana words with a similar frequency by a similar frequency and embedded in the same sentence frames as the semantically correct sentences were used as foils or controls. For instance, for the target word "organ", "England" was selected because both words have similar frequency. In the same sentence context of the semantically correct sentence, the parallel semantically incorrect sentences were "*England* is an musical instrument." イギリスは楽器です。(target in katakana) and いぎりすは楽器です。(target in hiragana). The corresponding 20 semantically incorrect sentences embedded ten pairs of the slightly different target words are also written in the usual katakana script or the less familiar hiragana script.

Procedure: The same procedure as in Experiment 1 was followed. The subjects were asked to decide accurately and rapidly if the target words embedded in short sentences shown on the microcomputer screen belonged to particular semantic categories (i.e., whether the sentences were semantically correct) and were given appropriate feedbacks. Again, with no vocal interference and vocal interference conditions were used as in Experiment 1.

Results

The reaction time scores for each child was first edited for outliers with 2.5 standard deviations above and below the mean RT as being the upper and lower limits. The mean accuracy rates for the 3 grades with and without vocal interference were 88.82% and 88% respectively. An initial 3(grade) × 2(reading level) × 2(meaningfulness) ANOVA with the last factor repeated shows the expected advantage of meaningful sentences with the correct target words over the meaningless ones ($F(1, 102)=49.28$, $p<.001$) and no interaction effects. Since the semantically incorrect sentences were used as foils or controls and were of no direct interest, further statistical analyses were carried out only with the semantically correct sentences with the correct target words in the two scripts.

The main analyses examined the effects of vocal interference on semantically correct sentences with target words in usually written katakana or in the equivalent

Table 2. Means and Standard Deviations (in Parentheses) for Reaction Time of Lexical Decisions by Grade, Reading Level, Script and Vocal Interference (VI)

Grade	Reading Level	Semantically Correct Sentence				Semantically Incorrect Sentence			
		Without VI		With VI		Without VI		With VI	
		KT	HG	KT	HG	KT	HG	KT	HG
4	Skilled	1081 (275)	1181 (283)	1307 (365)	1329 (299)	1281 (300)	1387 (306)	1399 (324)	1512 (375)
	Less Skilled	1377 (323)	1425 (338)	1546 (381)	1670 (431)	1549 (385)	1536 (403)	1697 (402)	1854 (422)
5	Skilled	914 (159)	1010 (189)	991 (181)	1060 (267)	1098 (227)	1210 (254)	1139 (269)	1231 (304)
	Less Skilled	1382 (283)	1536 (347)	1616 (382)	1782 (347)	1570 (279)	1751 (303)	1780 (342)	1798 (323)
6	Skilled	896 (162)	1006 (195)	880 (205)	980 (251)	1043 (197)	1158 (199)	1052 (241)	1153 (295)
	Less Skilled	1132 (239)	1267 (273)	1208 (251)	1271 (249)	1383 (217)	1492 (258)	1417 (201)	1488 (196)

Note: KT refers to Katakana target words, and HG refers to Hiragana target words.

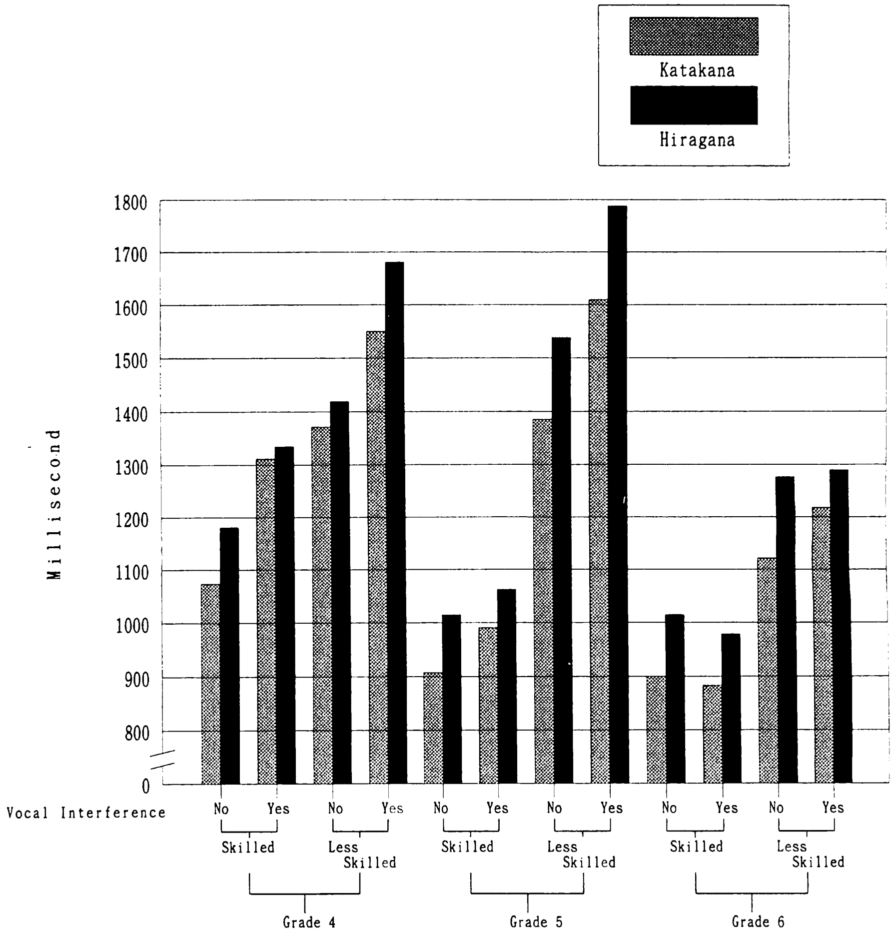

Fig. 2. Mean reaction time of processing target katakana and hiragana words in semantically correct sentences by grade, reading level, and articulation condition.

hiragana words. In a 3(grade) × 2(reading level) × 2(meaningfulness) ANOVA with the last two factor repeated, the main effects were all highly significant at the .0001 level: (Grade $F(2, 102)=14.28$, reading level $F(1, 102)=72.08$, vocal interference $F(1, 102)=18.80$, script $F(1, 102)=62.37$). As with Experiment 1, older students and skilled readers processed the sentences more efficiently than the younger students or less skilled readers. Vocal interference retarded the processing of both types of kana scripts as compared with the no interaction condition. Sentences with target words in katakana were processed faster (M=1194 msec.) than the corresponding sentences with the same target words written in hiragana (M=1293 msec.). However, there were also significant interaction effects between grade and reading level ($F(2, 102)=4.21$, $p<.05$). Thus, the significant main effects would need to be interpreted with some caution. These results are summarized in Table 2 and Fig. 2.

Collapsing across grades and reading levels, the mean RT increase as a result of vocal interference compared with the no interference condition in the semantic decision of the target words in typical katakana was 747 msec. and of the same target words in hiragana was 667 msec. It should be emphasized that this unexpected trend was masked by a number of factors. It further analyses and collapsing across grades, the overall mean effect sizes for the skilled readers show an increase of 95.6 msec. for katakana target words and 57.3 for the equivalent hiragana words. However, for the less skilled readers, the corresponding increases were 159.7 msec. for katakana and 165 msec. for hiragana. It would thus appear that vocal interference affected less skilled readers much more than skilled ones, and also retarded the processing of scripts for the younger children as compared with the older ones.

General Discussion

The two experiments in the study examined the effects of vocal interference on two scripts of the Japanese writing system (between kanji and hiragana target words in Experiment 1 and between katakana and hiragana target words in Experiment 2). Results suggest that the commonly-used target words written in kanji or katakana could normally be processed more directly than the same words written in hiragana and also embedded in the same sentence frames. In Experiment 2, because all the target katakana words were chosen from alphabetic loanwords normally written in katakana, semantic judgments at the sentence level with the target katakana words should be cognitively less demanding than the same target words written in hiragana. This should be reflected in shorter reaction times for processing the katakana target words as compared with their equivalent hiragana words. Thus, the choice of direct and indirect routs could be influenced by the script types familiar to the subjects for the kanji and katakana words in the two experiments. There is some evidence in previous studies that high-frequency or familiar katakana words could be accessed more directly than low-frequency ones (Besner & Hildebrandt, 1987; Hirose, 1984; Sasanuma, Sakuma & Tatsumi, 1988), even though it is generally assumed that phonetic recoding is necessary with kana.

Vocal interference in both experiments seemed to indicate that the processing of both kanji and kana words were affected. One possible explanation is that for lexical decisions involving target words written in kanji and kana scripts the sentence contexts would need to be kept in working memory with phonetic code and this code might be disturbed with vocal interference. If so, even though commonly-used kanji words and the alphabetic loanwords chosen in Experiments 1 and 2 are almost always written in kanji or katakana, they, as well as the equivalent hiragana words, could all involve phonetic recoding for semantic judgments at the sentence level.

The results for both experiments suggest that the less skilled readers, as compared with skilled ones, were more affected by vocal interference in processing kanji and hiragana target words in semantic contexts. It is likely that these less skilled readers may have difficulty in storing sentence contexts in working memory to make lexical decisions. Further more, the younger readers were less efficient in making the lexical decisions as compared with their older readers. Thus, the nature of the Japanese scripts to be processed, the grade and reading levels of the children all interact to affect the efficiency of lexical access.

While the speech code is important in learning an alphabetic language such as English (Perfetti & McCutchen, 1982) and in the regular kana, there are still many questions in delineating the locus of the speech code. The present study provides some evidence with Japanese readers that a number of factors such as the task and processing characteristics and the ability of the children will need to be taken into account.

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