Use of phonological information in processing kanji and katakana by skilled and less skilled Japanese readers

CHE KAN LEONG[1] and KATSUO TAMAOKA[2]
[1] *Department for the Education of Exceptional Children, College of Education, University of Saskatchewan, Saskatoon, Canada*; [2] *College of Business Administration, Matsuyama University, Matsuyama, Japan*

ABSTRACT: The study examined in the biscriptal Japanese orthography if phonological processing may accompany accurate and rapid visual recognition of single kanji characters according to their semantic or phonetic constituent elements, and high- and low-frequency katakana words. The subjects consisted of 108 grades 4, 5, and 6 Japanese children dichotomized into skilled and less skilled readers. The concurrent articulation interference paradigm was used while the subjects were making the lexicality decisions. The results suggest that visual-phonetic recoding may be possible in accessing difficult kanji characters with phonetic elements; and that phonological processing may vary according to the frequency of the katakana words. Further, younger children and less skilled readers are less efficient in their maintenance of the phonological code in processing the kanji and kana lexical items.

KEY WORDS: Concurrent articulation, Kanji processing, Katakana processing, Skilled and less skilled Japanese readers, Visual recognition

INTRODUCTION

There is now considerable evidence in the neuropsychological literature that the processing of the morphemically based kanji and the phonologically based kana scripts by Japanese aphasic patients is dissociable (Sasanuma 1975; Sasanuma & Fujimura 1971). The early clinical studies have shown differential cerebral laterality effects in the visual perception of kanji and kana scripts by adult pathological subjects. Current studies have tended to emphasize the interaction of stimulus types (kanji and kana) and task demands in inferring functional hemispheric asymmetries (for reviews, see Hoosain 1991; Paradis, Hagiwara & Hildebrandt 1985). The general findings of a progression of inferred hemispheric involvement as a function of stimulus-task interaction have been extended to experimental, psychological literature with normal adult Japanese subjects in lexical decision of kanji materials (Hatta 1981); and with Chinese students in lexical decision tasks with the analogous Chinese script (Leong, Cheng & Mulcahy 1987; Leong, Wong, Wong & Hiscock 1985).

Current psychological and neuropsychological findings suggest that lexical access to an alphabetic script such as English may not be *exclusively* phono-

Reading and Writing: An Interdisciplinary Journal 7: 377–393, 1995.

logical (Frost & Katz 1992); just as phonetic recoding may be used some of the times for a morphemic script such as Chinese (Chen & Tzeng 1992). With the biscriptal Japanese syllabary it has been shown that adult subjects name words normally written in katakana faster than words normally written in kanji, presumably by reference to an 'orthographic lexicon' (Besner & Hildebrandt 1987). The Besner and Hildebrandt notion of an orthographic lexicon in processing unconventional katakana is supported by a lexical decision experiment by Yamada, Imai & Ikebe (1990). There is evidence that the reading of complex kanji characters by adult Japanese subjects involves the activation of the opaque components as part of the visual recognition process of these characters (Flores d'Arcais & Saito 1993). The present study was prompted by the above findings and the assertion by Morton & Sasanuma (1984: 40) that 'some visual-phonetic conversion is possible with kanji, or that some direct access to semantic or syntactic processes might occur with kana'. In addition, there is the larger issue of the nature of the code that subserves different orthographies as a function of their mapping to phonology (Besner 1987).

KANJI AND KANA SCRIPTS IN THE JAPANESE ORTHOGRAPHY

As a preliminary, we provide below a short account of the nature of the biscriptal Japanese orthographic system. Strictly, the terms 'script' and 'orthography' differ in that the former generally refers to written symbols making speech visible, whereas the latter relates to more complex *lexical* representation (Sampson 1985). For the purpose of this paper, the terms script, writing system and orthography are used interchangeably.

The Japanese orthography consists of two scripts: kanji and kana. Kanji words, originally derived from Chinese with their different layers of pronunciations are used for lexical morphemes; and kana words denote grammatical morphemes. There are two kinds of kana, each with 46 basic symbols which are augmented to 71 with the use of diacritics. Hiragana (cursive kana) words are used for inflexions and grammatical structures; and katakana (square kana) words are used for foreign loan words other than those borrowed from Chinese, for some onomatopoeic words, and for the names of some flora and fauna, which would otherwise need very rare kanji.

Kanji

For kanji words, the original Chinese reading or pronunciation is known as *on-reading* (on meaning sound), and the Japanese reading is known as *kun-reading* (kun meaning explanation). An example of on-reading for the equivalent of 'horse' is /ba/ and kun-reading is /uma/; and another example for 'east' is the on-reading of /to/ as in Tokyo (eastern capital) and the kun-reading of /higashi/ pronounced as /hi-ga-shi/ with an equal length of time

duration. Amongst on-readings, go-on is the usual pronunciation for words of modern Japanese pertaining to Buddhism terms; *kan-on* is used for terms connected with Confucianism; and *to-on* (formerly *so-on*) is influenced by Zen Buddhists. In practice, the readings of many common Chinese loan words in contemporary Japanese are the results of the blending of these different renderings (Kaiho 1984; Paradis et al. 1985); and kan-on readings going back to the Han Dynasty of China seem to predominate. Many kanji words also have multiple on-readings and kun-readings for historical reasons.

Typically, the original Chinese on-morphemes tend to be bound morphemes and appear mostly in words with compound characters. An example is /san/ meaning mountain in the reading of Fujisan or Fujiyama. The latter reading /yama/ in Fujiyama is an example of kun-reading as a free form. It must be emphasized that singly kanji words often have different pronunciations, sometimes on-readings and sometimes kun-readings. It has been estimated that on-readings of kanji are considered more probable because of frequency of occurrence as compared with kun-readings and because of the possibility of resorting to the phonetic radicals (sometimes called 'section heads' inherent in a number of kanji words as guides in pronunciation (Paradis et al. 1985; Pye 1971).

Many kanji characters can be decomposed into 214 basic, constituent elements known as 'radicals'. The radicals are classified into these categories according to their spatial arrangement: *hen* (side), *tsukuri* (building), *kanmuri* (crown), *ashi* (leg), *kamae* (structure), *tare* (hanging), and *nyo* (entering). Knowledge of these basic elements and of their structural arrangement facilitates recognition and learning of all acquired kanji characters. The 214 radicals can be further classified as 'phonetic' and 'semantic', and according to one count by Ito (1979) there are 1,278 phonetic compound kanji out of 1,933 kanji characters. Ito further suggested that the understanding of these phonetic and semantic elements as building blocks would help the efficient mastery of kanji. For example, the basic kanji character of /haku/ (meaning 'white') in on-reading, or /shiro/ in kun-reading, is often used to construct new kanji characters as shown in Figure 1. These new kanji characters are still read as /haku/ from the original on-reading of the basic kanji character.

Japanese children learn hiragana when they start reading and are introduced progressively to kanji and foreign loan words through katakana, although they will have been exposed to the kana-phonology correspondence long before

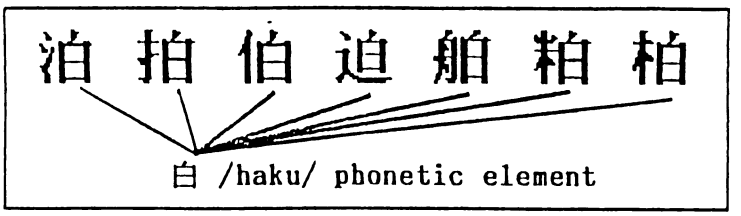

Figure 1. The use of phonetic element.

that. For elementary and high school students, the Japanese Ministry of Education stipulates the specific kanji characters to be learnt from the list of 1850 kanji characters for current use or *Toyo Kanjihyo* (Tk list) as : 76, 145, 195, 195, 195, and 190 for grades 1 to 6 respectively, and the rest at the junior high school level from grades 7 to 9 (Seeley 1984). The TK list of 1850 characters together with the guide lines for their use helps the writing of Japanese texts and school learning. A modified list of kanji for general use or Joyo Kanji (JK List) contains 1945 kanji including kanji combinations with irregular kun-readings, and aims at the needs of writing modern Japanese for the 1980s and beyond.

Kana

Each Japanese kana symbol represents a speech unit known as *mora*. A mora is more of a subsyllabic unit on which the rhythm of the Japanese language is based (Otake, Hatano, Cutler & Mehler 1993), and morae are pronounced with approximately equal durations. For example, the Japanese word /watashi/ for 'I' is pronounced with approximately equal durations as /wa/, /ta/, and /shi/ . In addition to being a unit to measure phonological distance, the mora as a timing unit and a unit to segment speech in both speech perception and production is more specific to Japanese (Kubozono 1989, 1993).

Mora constructions can take these possible combinations: (a) the five single vowels of /a/, /i/, /u/, /e/, or /o/; (b) consonant-vowel combinations with these seven consonants: /k/, /s/, /t/, /n/, /h/, /m/ , and /r/; (c) the five semivowel-vowel combinations (/ya/, /yu/, /yo/; /wa/ and /wo/); (d) consonant-semivowel-vowel combinations; and (e) a nasal coda representing /n/, /m/, or /ŋ/, depending on phonetic contexts (Tamaoka 1991). Of the 101 mora combinations represented by 104 kana symbols, consonant-vowel combinations predominate with 58 mora combinations and this is followed by consonant-semivowel-vowel combinations with 33 different mora combinations.

The five vowels, their combinations with the seven consonants and two semivowels plus the single nasal /n/ provide the 46 basic morae. These speech units are augmented by 25 more morae formed through the combinations of the five vowels and the consonants /g/, /z/, /d/, /b/, and /p/ with the use of diacritics shown as two small dots or strokes to indicate voiced consonants and a small circle to show an initial voiceless labial plosive /p/. In addition, there are 33 sounds formed by the semivowel /y/ and 11 consonants in combination with the vowels /a/, /u/, and /o/ to make for a total of 104 kana symbols.

Commentary

It should be emphasized that the Japanese speaker uses one writing system which integrates the scripts of kanji and kana. Kanji symbols appear visually complex, depending on the number of strokes. The multiplicity of on-readings

and kun-readings and the absence of tones as used in the original Chinese all make for a considerable degree of homophony. The homophony will need to be disambiguated with the use of context. For single kanji characters, readers may choose the more frequent on-readings. They may also rely on the phonetic components or radicals in complex characters as guides for close approximations of pronunciations. This aspect is emphasized by Saito, Inoue & Nomura (1979). That the phonetic radicals provide effective mnemonics can also be seen from an estimate by Ito (1979) of the preponderance of phonetic radicals in kanji characters: 56% of the 996 kanji and 66% of the 1211 kanji taught by the end of grades 6 and 9 respectively.

In katakana there are also many homophonic words (Iwabuchi 1987). An example is the same pronunciation /gurama/ for the words 'grammar' and 'glamour'. This is because in Japanese there is no sound distinguishing between /r/ and /l/. Similarly, 'valve' and 'bulb' are both pronounced as /barubu/ because the /v/ and /b/ sounds are indistinguishable. Occasionally, the pitch accent is used to distinguish homophonic words as show in /hashi/ with high pitch for /ha/ and a low pitch for /shi/ to mean chopsticks and a low pitch for /ha/ and a high pitch for /shi/ to mean bridge. But there are dialectical differences which militate against this system of disambiguation. The ambiguity is minimized with the combination of kanji to provide both visual prominence and lexical meaning.

THE STUDY

The overall aim of the study was to test the observation of Besner (1987) and Morton & Sasanuma (1984) that access to kanji does not preclude some visual-phonetic processing and that kana might involve some direct lexical access. Specifically, the two experiments, both at the word level with one involving single kanji characters and the other involving katakana words, were designed to delineate in some way the locus of phonetic recoding and visual access in accurate and rapid visual recognition of kanji and katakana words by children with varying reading proficiency at three grades.

Concurrent articulation. To test the involvement of phonetic recoding, concurrent articulation was used while the subject made lexical decisions on the lexicality of the kanji characters or katakana words shown visually on the microcomputer screen. The basic vocal interference paradigm was that used by Kleiman (1975), Levy (1975, 1977), Baddeley (1986) in reading English, and in particular by Kimura (1984) in reading Japanese.

Kleiman (1975) asked his adult subjects to shadow a stream of auditorily presented digits to suppress speech recoding while making lexical decisions of word pairs (did they rhyme or did they look similar graphemically?) or sentences. He found a more deleterious effect (a larger decrement) on phonemic and comprehension judgments than on graphemic or synonymity

judgments. From these results Kleiman suggested that speech recoding of visually presented verbal materials took place at the working memory stage rather than at the lexical access stage. Similar results of a speech-based process as a holding code for parsing and semantic integration of words were also found by Levy (1975) with vocal interference (subjects counting while reading). Levy (1977, Experiments 1 & 2) subsequently showed that counting adversely affected both lexical and semantic detection when sentences were presented as a reading task in the visual mode, but not as a general language task in the listening mode. Furthermore, her data were consistent with the working memory hypothesis since the interference decrement was not consistent after about three sentences. Her Experiment 3 with thematic paragraphs found that thematicity and suppression effects made independent contribution to recall, and raised the important point of the independence of meaningfulness and speech suppression effects (see also Levy 1978). Baddeley (1986) suggested that reading for meaning depended more on the articulatory mechanism than on memory or attention.

Drawing on the above studies, Kimura (1984) asked 24 adult Japanese subjects to make synonymity judgments of pairs of monomorphemic words written in kanji or hiragana with or without concurrent articulation (subjects saying aloud in Japanese the numbers 1 to 5 repeatedly). She found that concurrent articulation adversely affected the reading (visual recognition for meaning) of hiragana, but not the same item-pairs written in kanji. Kimura interpreted her results to mean that vocal interference interrupted prelexial phonological coding in kana. This claim is too strong in that the one experiment in her study was not designed to test pre- and post-lexical processing. It is more likely that working memory is implicated.

In particular, there are several flaws in the stimulus materials used by Kimura (1984), which may affect her results and her claim. First, some of the item-pairs did not satisfy the synonymity or relatedness in meaning requirement (e.g., 'spirit-body' , 'train-commute' , 'history-modern times'). Second, there was the 'strangeness' or unfamiliarity effect for equivalent item-pairs written in hiragana when these items or pairs are almost always written in kanji. Third, at least 7 of the item-pairs out of 30 written in hiragana contain homophonic kana words which would impede synonymity decision time. An example is 'kyoukai' which could mean church, association or border.

It is not known if the flaws in the design of stimulus items may have accentuated Kimura's findings. Still, the results are of interest in that they suggest concurrent articulation may impede phonetic recoding, at the level of the mora or syllable. Similar results were obtained with 24 grade 1 Japanese children with a picture-word (kanji and hiragana) matching task by Kimura & Bryant (1983, Experiment 1). More recently, Kinoshita & Saito (1992) in their study (especially Experiment 3) of a phonological lexical decision task, where stimuli were kana-transcribed words usually written in kanji, found a lack of effects of concurrent articulation. These researchers interpreted the results of

their 3 experiments to mean that concurrent articulation may not disrupt the generation of phonology, but may impair its maintenance. This interpretation provides another perspective to explain Kimura's (1984) finding of considerable concurrent effects for kana-transcribed words.

EXPERIMENT 1

Experiment 1 was a lexical decision task involving singly kanji characters. Japanese children in grades 4, 5 and 6 with varying reading proficiency (skilled and less skilled) were required to decide accurately and quickly the lexicality of visually presented difficult singly kanji characters and pseudo kanji characters on the basis of the overall configurations or the phonetic radicals or components of these individual items. The rationale is that visual or direct access is used at the configural level of lexical decision of kanji and that the analysis and synthesis of the phonetic radicals would impede processing time and would be more susceptible to interference from concurrent articulation. Further, the efficiency in processing the kanji characters and the degree of vocal interference would vary according to the grade and reading levels of the children.

Method

Subjects. The 108 students for the study were selected from a larger pool of over 200 subjects from a medium-sized elementary school in a large city in 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, 137.93 and 149.42 months with standard deviations 4.03, 3.11 and 3.26 months. The mean reading ages with standard deviations on the TK Reading Ability Test (Kitao 1984) for the grades 4, 5 and 6 groups of 36 children each were respectively: 84.46 (30.32), 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 materials. The stimuli were 20 real single kanji characters with on-reading phonetic radicals and 20 real single kanji characters with overall configurations not decomposable into phonetic elements; and two sets of corresponding 20 'phonetic' and 20 'semantic' pseudo kanji characters constructed generally by reversing the elements or configurations in left-to-right or up-down rotations. The mean number of strokes for each of the categories of the real and pseudo kanji characters was 10. The characters are not in the Toyo Kanji List for grades 1 to 9, and could be assumed to be unfamiliar to the children, although they would know the phonetic elements forming integral parts of the phonetic kanji characters.

The use of difficult or unknown kanji characters should rule out the familiarity effect; the control for stroke number should minimize iconicity or complexity effects; and the intra-word comparison within the same kanji script rather than the typical inter-script comparison should reduce confounds from 'strangeness' or length-of-grapheme effects. The main condition of interest was that of the phonetic and semantic elements inherent in the single kanji characters and the possible interference effects of concurrent articulation on lexical decisions of items with these different components.

Procedure. The general instruction to all subjects in both the concurrent articulation and no-articulation conditions was that they had to decide accurately and rapidly on the basis of component parts or configurations of the kanji characters shown individually on the microcomputer screen whether the items were real or pseudo characters. The 40 real and 40 pseudo kanji characters were presented at random at the rate of 200 milliseconds (ms) per items, and appropriate feedbacks were given to the subjects at the end of each trial. The subjects within each grade, reading level, and each gender were randomized into subgroups with one subgroup taking the no-articulation condition first, followed in about 30 days' time with the articulation condition; and with the other subgroup reversing the procedure.

For the articulation condition, subjects were asked to count aloud repeatedly in Japanese the numbers 1 to 10 at the rate of about 3 items per second while making the lexicality decision. This concurrent articulation rate has been shown to be adequate to produce suppression on tasks involving phonological coding, but not in the subject's general processing of information (Baddeley 1986). Subjects were asked to respond by pressing on the microcomputer a YES key to signify a real kanji character or a NO key to signify a pseudo kanji character. The hands used for the YES or NO responses were counter-balanced within and across subjects. The YES/NO responses yielded both accuracy and reaction time measures which were recorded on the hard disk for statistical analyses.

Results

The 80 RT measures for each child were first edited for outliers with 2.5 standard deviations above or below the mean RT as generally the upper or the lower limits (Comrey 1985). The mean accuracy rate for the 3 grades with and without concurrent articulation were respectively 77 and 79 percent. A preliminary 3 (grade) × 2 (reading level) × 2 (lexicality) ANOVA with the last factor repeated using correct edited RT scores shows the expected faster processing of real over pseudo kanji characters $F(2, 102) = 12.33$; $p < 0.0001$], and no interaction effects. Since the pseudo characters were used as foils and were not of direct interest, further analyses were carried out only with the correct RT scores of the real kanji characters.

The main analyses examined the effects of concurrent articulation on the

processing of kanji characters in relation to grade and reading levels. In a 3 (grade) × 2 (reading level) × 2 (articulation condition) × 2 (kanji element) ANOVA with the last two factors repeated, the main effects for grade, reading level, concurrent articulation, and kanji element were all highly significiant in the expected direction [$F(2, 102) = 18.91$ for grade; $F(1, 102) = 41.28$ for reading level; $F(1, 102) = 6.78$ for articulation condition; and $F(1, 102) = 16.10$ for kanji element respectively]. There were no interaction effects. The results are summarized in Table 1 and in Figure 2.

Discussion

Careful analysis of the data in relation to Table 1 and Figure 2 shows that, collapsing across grades, kanji elements and articulation or no-articulation conditions, less skilled Japanese readers lagged behind their skilled peers by about 200 ms on the average in their lexical decision of kanji characters. This result is in line with the general findings of the efficiency hypothesis in that less skilled readers are less accurate and less automatic, as compared with their skilled peers, in processing elementary lexical items [English] (Perfetti 1985).

The relative mean reaction time differences in the processing of kanji characters with predominantly semantic or predominantly phonetic elements with and without articulation, and collapsing across reading levels and grades, were 46.13 ms and 85.17 ms respectively, both favoring the no-articulation condition. The mean difference lexical decision latency of kanji characters with

Table 1. Means and standard deviations (in parentheses) of lexical decision reaction time (ms) of kanji characters with and without concurrent articulation

Grade	Reading level	Without articulation		With articulation	
		With 'semantic' elements	With 'phonetic' elements	With 'semantic' elements	With 'phonetic' elements
4	Skilled	952 (201)	990 (170)	1022 (254)	1067 (315)
	Less skilled	1184 (273)	1224 (259)	1305 (318)	1291 (311)
5	Skilled	806 (133)	831 (150)	886 (197)	961 (253)
	Less skilled	1030 (221)	1068 (229)	1165 (283)	1212 (239)
6	Skilled	757 (162)	802 (182)	745 (190)	765 (211)
	Less skilled	941 (251)	959 (268)	944 (233)	989 (234)

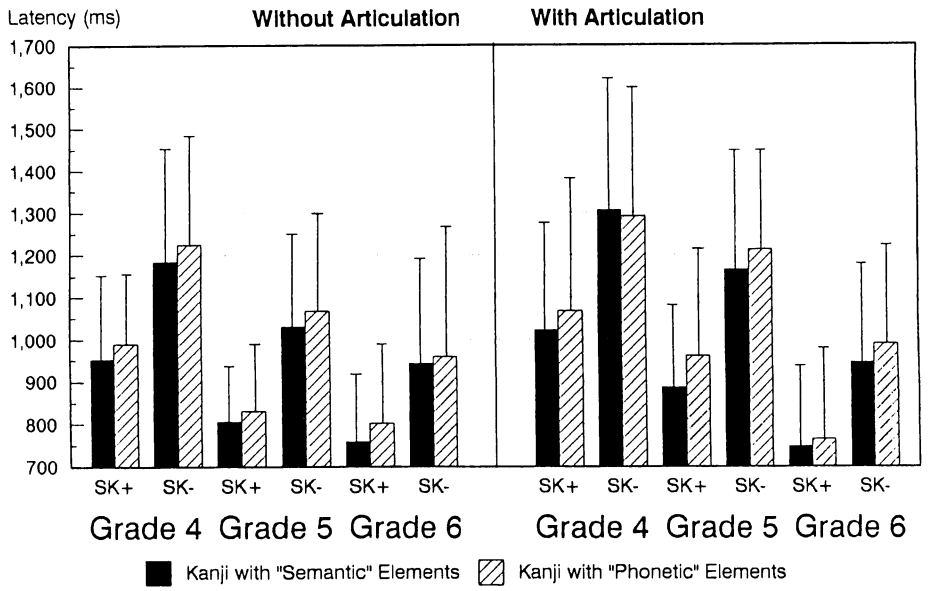

Figure 2. Lexical decision of **kanji** characters by 108 grades 4, 5 and 6 Japanese readers.

semantic elements of 46.13 ms in favor of no-articulation condition, as compared with the concurrent articulation condition, is considerably smaller than the mean difference RT of the corresponding kanji characters with phonetic elements of 85.17 ms, also in favor of the no-articulation condition. Again, the less skilled readers were more retarded in both the semantic and phonetic conditions, as compared with their skilled peers. These results are in line with the general findings in the literature that concurrent articulation retards the decision of lexicality of lexical items, especially for those items constructed more on a phonetic basis, and more so for less skilled readers.

EXPERIMENT 2

The results of Experiment 1 suggest that rapid visual recognition of kanji characters by Japanese readers may be accompanied by phonological processing, at least some of the time, and with varying effects according to the phonetic or semantic composition of the kanji characters. If so, the degree of phonologically mediated processing of the phonetic kana could likely be affected by some linguistic variables and one of these could be the printed frequency of the kana words used. This line of reasoning is based, in part, on the experiments of Seidenberg (1985) that the retrieval of phonology is more important and has a more deleterious effect in processing low frequency English words and Chinese characters in these two disparate orthographies, as compared with high frequency English and Chinese lexical items. It could thus be reasoned that the translation of regular katakana graphemes into sound

forms could be impeded by concurrent articulation, and the interference would be more marked with low frequency than high frequency katakana words. The adverse effects should also vary according to grades and reading levels of the children. Experiment 2 was designed to test these hypotheses.

Method

Subjects. The same 108 grades 4, 5 and 6 Japanese students, who had completed Experiment 1 under both the concurrent articulation and no-articulation conditions, also served as subjects for Experiment 2.

Stimulus materials. Thirty high frequency and 30 low frequency katakana words were selected from the list by Ogawa (1972). The mean frequency index for the high frequency katakana words was 177.40 and for the low frequency ones was 20.57, and the mean number of morae for both groups of words was 4.47. Sixty corresponding pseudo katakana strings were constructed by changing one mora (one katakana symbol) of each of the real katakana words while maintaining the same number of morae for the respective words. An example of a high frequency katakana word was 'piano' /piano/ with an index of 231 and this real katakana word was matched with the pseudo katakana /piari/. An example of a low frequency katakana word was 'horn' /horun/ with an index of 45 and this real word was matched with a pseudo katakana string pronounced as /horen/.

Procedure. The experimental procedure was similar to that of Experiment 1 for both the concurrent articulation and no-articulation conditions. The subjects were asked to decide accurately and rapidly if the 120 items shown individually on the microcomputer screen were real or pseudo katakana words by pressing the YES or NO keys. As with Experiment 1, presentation of the items was randomized and the hands used for the YES or NO responses were counter-balanced within and across subjects. The responses yielded both accuracy and reaction time measures for analyses.

Results

The 120 reaction time measures for each child were first edited for outliers with 2.5 standard deviations above and below the mean RT as generally the upper and lower limits. The mean accuracy rates for the 3 grades with and without vocal interference were respectively 78%. A preliminary 3 (grade) × 2 (reading level) × 2 (lexicality) ANOVA with the last factor repeated shows the expected advantage of real katakana words over pseudo ones [$F(1,102) = 9.98$; $p < 0.01$]. There was also a significant grade × reading level interaction [$F(1,102) = 5.29$; $p < 0.01$]. Since the pseudo katakana strings were used as foils and were of no direct interest, further analyses were carried out only with the real katakana words.

The main analyses examined the effects of concurrent articulation on the high and low frequency katakana words. In a 3 (grade) × 2 (reading level) × 2 (articulation condition) × 2 (frequency) ANOVA with the last two factors repeated using correct RT scores, the main effects for grade, reading level, articulation condition, and frequency were all highly significant in the expected direction [$F(2, 102) = 13.23$; $F(1, 103) = 47.06$; $F(1, 102) = 20.71$; and $F(1, 102) = 391.25$ respectively]. There were also significant interactions: grade × reading [$F(2, 102) = 4.54$]; reading × frequency [$F(1, 102) = 19.07$], articulation condition × frequency [$F(1,102) = 4.72$], and grade × reading × frequency [$F(2, 102) = 3.16$]. Thus the significant main effects would need to be interpreted with caution. The means and standard deviations of the RT measures are shown in Table 2 and displayed in Figure 3.

Further separate analyses collapsing across grades for skilled and less skilled readers on the concurrent articulation effects show highly significant interference effects with $F(1, 53) = 8.43$ for skilled readers and $F(1, 53) = 13.13$ for less skilled readers. In addition, the articulation × frequency interaction was significant only for less skilled readers [$F(1, 53) = 4.40$].

Discussion

Careful study of the data in relation to Table 2 and Figure 3 shows that collapsing across grades and both high and low frequency katakana words, less skilled Japanese readers lagged behind their skilled peers by about 207 ms in processing the items in the no-articulation condition and 311 ms in the

Table 2. Means and standard deviations (in parentheses) of lexical decisions reaction time (ms) of katakana words with and without concurrent articulation

Grade	Reading level	Without articulation frequency		With articulation frequency	
		High	Low	High	Low
4	Skilled	904 (184)	1137 (305)	996 (239)	1194 (328)
	Less skilled	1066 (214)	1296 (335)	1150 (314)	1396 (301)
5	Skilled	779 (124)	921 (187)	832 (177)	1028 (258)
	Less skilled	1102 (265)	1386 (333)	1244 (239)	1611 (336)
6	Skilled	724 (126)	845 (172)	751 (163)	891 (220)
	Less skilled	850 (188)	1055 (230)	939 (228)	1220 (289)

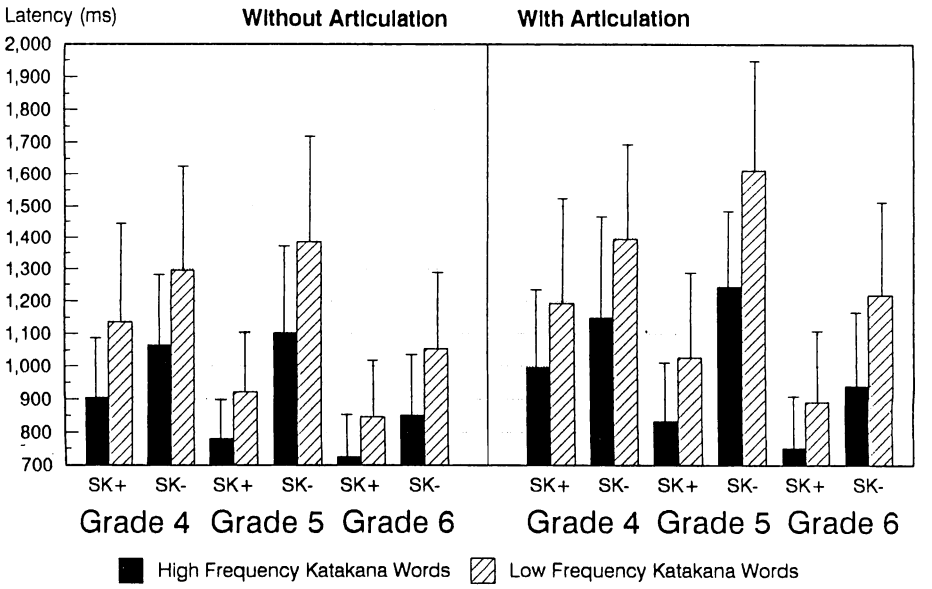

Figure 3. Lexical decision of **katakana** words by 108 grades 4, 5, and 6 Japanese readers.

articulation condition. Again, this result is in line with the verbal efficiency hypothesis (Perfetti 1985).

The relative mean reaction time differences in the processing of high frequency katakana words in the two interference conditions was 64.50 ms, as compared with the corresponding difference of 116.66 ms for the low frequency katakana items. For the latter category of katakana, the skilled readers across grade levels showed a mean RT difference of 70 ms, as compared with a mean difference of 153.23 for the less skilled readers of interference effect for the same low frequency katakana items. For the high frequency katakana words the mean RT processing difference between the vocal interference and no interference conditions was negligible for the skilled readers, and 105 ms for the less skilled readers.

Taken together, the above results suggest that while concurrent articulation retarded the lexical decision of the lexicality of the katakana words, the younger and less skilled readers were affected more adversely by low frequency than by high frequency katakana words and as compared with older and more skilled readers. This interpretation is reinforced by the separate analyses for the skilled and less skilled readers.

GENERAL DISCUSSION

The two visual recognition experiments, one with single kanji characters and a complementary one with katakana words, attempted to delineate the involvement of phonological processing in the lexical decision of these two Japanese

scripts. The typical assumption that kanji is accessed directly through the visual or lexical route may not always apply, at least not with difficult or rare kanji characters. These difficult characters with phonetic components may be processed via some phonetic recoding, and consequently are susceptible to the influence of concurrent articulation. Vocal interference also has a greater adverse effect on younger children and on the less skilled readers. This line of reasoning is supported by findings that the processing of the analogous Chinese characters, from which kanji is derived, involves phonetic recoding at the working memory stage, at least some of the times, for Chinese text comprehension in mature readers (Hung & Tzeng 1981).

In a different way, the processing of the regular katakana is much more severely retarded by concurrent articulation because of the regular kana-phonology correspondence, as typically found in the clinical and experimental literature. Moreover, the deleterious effect is more on low frequency katakatana words and with younger and less skilled readers. Both sets of results provide some indirect support for the vocalization experiments of Seidenberg (1985), in which he found the time course of the phonological code to be more retarded with low frequency Chinese characters and English words, as compared with high frequency ones. Our findings also suggest that younger and less skilled readers are likely to have a lesser well developed phonological code; and that in their attempt to use this less efficient code to access the lexical items they are likely to be more retarded by concurrent articulation.

A question may be raised about the use in the study of single kanji characters and katakana words in that they are more susceptible to homophonic effects. However, by making intra-script comparisons (kanji with other kanji characters; katakana with other katakana words) as contrasted with the typical inter-script comparisons, and by careful control of such variables as complexity, and printed frequency, we hope to avoid or minimize some of the methodological problems in research into the differential processing of Japanese scripts, as cautioned by Paradis et al. (1985).

The use of concurrent articulation seems to bear out the observations by Besner (1987) and Kimura (1984) that the Japanese language, in particular kana, might be more closely tied to articulatory mechanisms, than is phonetic recoding in English. If so, this may explain our results of developmental differences with the 108 grades 4, 5 and 6 Japanese children. The concurrent articulation task in the present study seemed to be sensitive to individual differences in phonetic recoding in relation to the processing of the kanji and katakana lexical items.

In the present study no claim is made to the pre- or post-lexical processing of the lexical items, or that less efficient lexical processing 'causes' less skilled reading performance. The study was not designed to test these notions. Our results suggest that in the lexical access of single kanji characters with phonetic and semantic elements, visual-phonetic conversion may be possible or even necessary as a function of the nature of the stimulus materials. Our

data also show that in the lexical access of katakana words, the time course of the phonological processing may vary according to the frequency of the kana words.

Perfetti (1992) aptly points out that the concept of pre- and post-lexical processes depends on the definition of lexical access and the rapidity or automaticity with which this access takes place. In their discussion of reading English and Chinese characters, Perfetti, Zhang & Berent (1992) further emphasize that phonological processing is not all-or-none, but is probabilistic in nature. There is a role for phonology in identifying Chinese characters, just as we have found some evidence of phonology accompanying lexical access in the analogous kanji words. On the Perfetti account of phonology as an integral component in word identification, the time course in identifying kanji words with phonetic elements should therefore be longer than those with semantic elements and more susceptible to interference; and low frequency katakana words are more retarded by concurrent articulation. These hypotheses were borne out in the present study. Even though our study did not examine pre- or post-lexical processing, our results seem to support the position of Perfetti et al. (1992) that writing systems constrain the levels at which phonology is activated. Their emphasis on the 'retrieval' of phonology with reference to Chinese characters provides another explanation of the findings of Kinoshita & Saito (1992) that concurrent articulation impairs the maintenance and not so much the generation of phonology of kana-transcribed words. Both interpretations may underpin the results of our experiments.

ACKNOWLEDGMENT

The study was assisted in part by a grant from the Social Sciences and Humanities Research Council of Canada to C.K. Leong, and by a University of Saskatchewan Fellowship to K. Tamaoka. We are grateful for the assistance. We thank the teachers and students for their cooperation, and Takeshi Hatta of Nagoya University for his advice. The comments of the anonymous reviewers are also much appreciated. Any shortcomings are necessarily our own.

REFERENCES

Baddeley, A. D. (1986). *Working memory*. Oxford: Clarendon Press.

Besner, D. (1987). On the relationship between orthographies and phonologies in visual word recognition. In: A. Allport, D. Mackay, W. Prinz & E. Scheerer (eds.), *Language perception and production* (pp. 211–226). London: Academic Press.

Besner, D. & Hildebrandt, N. (1987). Orthographic and phonological codes in the oral reading of Japanese kana, *Journal of Experimental Psychology: Learning, Memory and Cognition* 13: 335–343.

Chen, H-C. & Tzeng, O. J. L. eds. (1992). *Language processing in Chinese*. Amsterdam: North-Holland.

Comrey, A. L. (1985). A method of removing outliers to improve factor analytic results, *Multivariate Behavioral Research* 20: 273–281.

Flores d'Arcais, G. B. & Saito, H. (1993). Lexical decomposition of complex Kanji characters in Japanese readers, *Psychological Research* 55: 52–63.

Frost, R. & Katz, L., eds. (1992). *Orthography, phonology, morphology, and meaning*. Amsterdam: North-Holland.

Hatta, T. (1981). Different stages of kanji processing and their relations to functional hemisphere asymmetries, *Japanese Psychological Research* 23: 27–36.

Hoosain, R. (1991). *Psycholinguistic implications for linguistic relativity: A case study of Chinese*. Hillsdale, NJ: Lawrence Erlbaum.

Hung, D. L. & Tzeng, O. J. L. (1981). Orthographic variation and visual information processing, *Psychological Bulletin* 90: 377–414

Ito, K. (1979). Keisei moji to kanji shido [Phonetic compound kanji and kanji teaching]. *Gengo Seikatu [Linguistic Life]* 326: 68–79.

Iwabuchi, E. (1987). *Nihongo o kangaeru [Considering the Japanese language]*. Tokyo: Koudansha.

Kaiho, H. (1984). *Kanji o kaga kusuru [Investigating kanji scientifically]*. Tokyo: Yuhikaku.

Kimura, Y. (1984). Concurrent vocal interference: Its effects on kana and kanji, *Quarterly Journal of Experimental Psychology* 36A: 117–131.

Kimura, Y. & Bryant, P. (1983). Reading and writing in English and Japanese: A cross-cultural study of young children, *British Journal of Developmental Psychology* 1: 143–154.

Kinoshita, S. & Saito, H. (1992). Effects of concurrent articulation on reading Japanese Kanji and Kana words, *The Quarterly Journal of Experimental Psychology* 44a: 455–474.

Kitao, N. (1984). *TK-shiki yominoryoku shindan kensa tebiki [Manual of the TK-style reading ability diagnosis test]*. Tokyo: Taken Publishing.

Kleiman, G. M. (1975). Speech recoding in reading, *Journal of Verbal Learning and Verbal Behavior* 14: 323–339.

Kubozona, H. (1989). The mora and syllable structure in Japanese: Evidence from speech errors, *Language and Speech* 32: 249–278.

Kubozona, H. (1993). Speech segmentation and phonological structure. Paper presented at the 1993 Dokkyo International Forum on Speech Perception and Phonology, Dokkyo University, Tokyo, Japan.

Leong, C. K., Cheng, P. W. & Mulcahy, R. (1987). Automatic processing of morphemic orthography by mature readers, *Language and Speech* 30: 181–197.

Leong, C. K., Wong, S., Wong, A. & Hiscock, M. (1985). Differential cerebral involvement in perceiving Chinese characters: Levels of processing approach, *Brain and Language* 26: 131–145.

Levy, B. A. (1975). Vocalization and suppression effects in sentence memory, *Journal of Verbal Learning and Verbal Behavior* 14: 304–316.

Levy, B. A. (1977). Reading: Speech and meaning processes, *Journal of Verbal Learning and Verbal Behavior* 16: 623–638.

Levy, B. A. (1978). Speech analysis during sentence processing: Reading and listening, *Visible Language* 12: 81–102.

Morton, J. & Sasanuma, S. (1984). Lexical access in Japanese. In: L. Henderson (ed.), *Orthographies and reading* (pp. 25–42). Hillsdale, NJ: Lawrence Erlbaum.

Ogawa, T. (1972). 52 no kategorii ni zokusuru go no shuttugen hindohyo [List of word frequencies in the 52 categories], *Jinmonronkyu [Kansai Gakuen University]* 32: 1–68.

Otake, T., Hatano, G., Cutler, A. & Mehler, J. (1993). Mora or syllable? Speech segmentation in Japanese, *Journal of Memory and Language* 32: 258–278.

Paradis, M., Hagiwara, H. & Hildebrandt, N. (1985). *Neurolinguistic aspects of the Japanese writing system*. New York: Academic Press.

Perfetti, C. A. (1985). *Reading ability*. New York: Oxford University Press.

Perfetti, C. A. (1992). The representation problem in reading acquisition. In: P. B. Gough,

L. C. Ehri & R. Treiman (eds.), *Reading acquisition* (pp. 145–174). Hillsdale, NJ: Lawrence Erlbaum.

Perfetti, C. A., Zhang, S. & Berent, I. (1992). Reading in English and Chinese: Evidence for a 'universal' phonological principle. In: R. Frost & L. Katz (eds.), *Orthography, phonology, morphology, and meaning* (pp. 227–248). Amsterdam: North-Holland.

Pye, M. (1971). *The study of kanji.* Tokyo: Hokuseido Press.

Saito, H., Inoue, M. & Nomura, Y. (1979). Information processing of kanji and kana: The close relationship among grapheme, phonemic and semantic aspects, *Psychologia* 22: 195–206.

Sampson, G. (1985). *Writing systems: A linguistic introduction.* Stanford, CA: Stanford University Press.

Sasanuma, S. (1975). Kana and kanji processing in Japanese aphasics, *Brain and Language* 2: 369–383.

Sasanuma, S. & Fujimura, O. (1971). Selective impairment of phonetic and non-phonetic transcription of words in Japanese aphasic patients: kana vs. kanji in visual recognition and writing, *Cortex* 7: 1–18.

Seeley, C. (1984). The Japanese script since 1900, *Visible Language* 18: 267–302.

Seidenberg, M. (1985). The time-course of phonological code activation in two writing systems, *Cognition* 19: 1–30.

Tamaoka, K. (1991). Psycholinguistic nature of the Japanese orthorgraphy, *Studies in Language and Literature* 11: 1–34.

Yamada, J., Imai, H. & Ikebe, Y. (1990). The use of the orthographic lexicon in reading kana words, *The Journal of General Psychology* 117: 311–323.

Address for Correspondence: Dr Che Kan Leong, Department for the Education of Exceptional Children, College of Education, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0

Phone: (306) 966 5257; Fax: (306) 966 8719; E-mail: leong@sask.usask.ca.