Processing of Hiragana and Katakana Scripts Under Limited Exposure Duration in a Japanese Patient with Mitigated Alexia with Agraphia

Tohoku Psychologica Folia
2006, **65**, 73 – 85

Processing of Hiragana and Katakana Scripts Under Limited Exposure Duration in a Japanese Patient with Mitigated Alexia with Agraphia

HAYASHI Atsuko (林　敦子)[1,2]

(Tohoku University)

OHIGASHI Yoshitaka (大東祥孝)[3]

(Kyoto University)

This paper examined the reading performance of a Japanese patient, MT, with mitigated alexia with agraphia. In our previous study (Matsunaga & Ohigashi, 1998), it was found that MT's reading thresholds for Hiragana nonwords were much higher than those for Katakana nonwords when letter length increased. In this study, we investigated her processing of Kana scripts at the letter level. First, she was administered a sequential letter matching task. When the inter-stimulus interval (ISI) of two letters was less than 1 second, MT showed a delay in the reaction time when Hiragana were presented first and followed by Katakana. MT's phonological processing of Hiragana was not done quickly. In order to explore the disturbance in Hiragana phonological processing, a reading aloud task was given as second task. She showed a delay in the reading time in Hiragana script only under the limited exposure duration. This suggested that the reading problem for MT was residual in the rapid phonological processing of Hiragana script, in comparison with that of Katakana, even if the reading deficits almost disappeared in the clinical situation.

Key words: Visual processing, phonological processing, Japanese, letter, short exposure duration

Introduction

In the Japanese writing system, there are two types of scripts, Kanji and Kana. Kanji characters are ideograms or logograms, which are of Chinese origin, and are used to write most content words. On the other hand, Kana are syllabic or moraic scripts, which are subdivided into two types of scripts, Hiragana and Katakana. These scripts have one-to-one correspondences between individual orthographies and their pronunciations. Hiragana characters are usually used

---

1. Department of Psychology, Graduate School of Arts and Letters, Tohoku University, Kawauchi, Aoba-ku, Sendai, 980-8576, Japan

2. Japan Society for the Promotion of Science, and Department of Behavioral Neurology and Cognitive Neuroscience, Tohoku University, 2-1 Seiryo-machi, Aoba-ku, Sendai, 980-8575, Japan. Part of this study was supported by a Grant-in-Aid for Scientific Research provided by the Japanese Ministry of Education, Culture, Sports, Science, and Technology.

3. Graduate School of Human and Environmental Studies, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto, 606-8501, Japan

for writing concrete nouns of Japanese origin or functional words and are originally a simplified cursive form of Kanji. In contrast, Katakana scripts are mainly used to represent foreign loan words (imported words) and are derived from a portion of Kanji form. Many studies have dealt with the dissociation between Kanji and Kana (especially Hiragana) in normal subjects (e.g., Hirose, 1984; Reuter-Lorenz & Brunn, 1990), aphasic and alexic patients (e.g., Iwata, 1984; Sasanuma & Fujimura, 1971; Sasanuma, 1974, 1980). Some studies have used Hiragana and Katakana words/nonwords as materials for manipulating orthographical familiarity (Besner & Hildebrandt, 1987, Hatta, Katoh, & Kirsner, 1984; Hirose, 1985; Komatsu & Naito, 1992; Yokoyama, 1991).

In normal subjects, Hatta et al. (1983, 1984) described that these scripts did not completely overlap, though they have same common lexical aspects. Usui (1998) demonstrated the difference between Hiragana and Katakana processing and suggested that it would be necessary to further investigate the coding speed of both scripts. In some aphasic or alexic patients, Hiragana words were much more difficult to read or write than Katakana words (Ohta & Koyabu, 1970; Sàsanuma & Fujimura, 1971; Yamadori, 1980). Most studies investigating Hiragana and Katakana reading have been run not at the letter level but the word level, there have been few studies examining the difference between Hiragana and Katakana scripts regarding letter processing, and little is known about the difference even for normal subjects.

In this paper, we investigated the feature of reading Hiragana and Katakana scripts in a patient (MT) with mitigated alexia with agraphia. Her reading deficits had almost disappeared clinically 4 years post on-set. In clinical examinations, it has been suggested that alexics with agraphia with left parietal lesions have deficits in Kana, in comparison with Kanji (Iwata, 1984; Yamadori, 1975, 1979). However, only few attempts have so far been made to investigate the nature of Hiragana and Katakana processing in detail. Matsunaga & Ohigashi (1998) measured MT's thresholds for reading. As a result, despite little difference between one-letter Hiragana and Katakana, her thresholds for Hiragana nonwords were much higher than those for Katakana nonwords, according to the increase in the letter length (Table 1). To examine her visual and phonological processing of Hiragana and Katakana scripts at the letter level, we investigated the reading impairments under tachistoscopic presentation conditions using a sequential letter matching task and a reading aloud task.

Table 1 MT's reading thresholds (msec)

Number of letters	Hiragana	Katakana
1-letter	100	90
2-letter word	180	90
nonword	600	200
3-letter word	180	100
nonword	850	550

Case Report

MT, a right-handed 63-year-old female with a high school education, suffered a hemorrhage in the left parietal lobe in February 1994. Resection of intra-cerebral hematoma was performed in March 1994. She showed Gerstmann's syndrome, mild anomic aphasia, alexia with agraphia and very slight constructional apraxia.

Clinical language examination revealed no kinesthetic facilitation and few problems in Kanji reading, even at the sentence level. However, in Hiragana, she showed paralexia of postpositional particles and read them with difficulty in May 1994. Two years later, she could read sentences normally and showed no paralexia in Hiragana at the Standard Language Test for Aphasia (SLTA) level presented in Table 2.

Table 2 MT's results in the Standard Language Test of Aphasia (SLTA)

Type	Tasks	Scores (March 5, 1996)
Listening	Kanji words	10/10
comprehension	Short sentence	10/10
	Oral commands	9/10
	Hiragana	10/10
Speaking	Naming (Kanji words)	10/10
	Naming (Hiragana words)	10/10
	Repetition (Words)	10/10
	Description Activities	10/10
	Narrative	6/6
	Repetition (Short sentences)	4/5
	Naming (Animals)	11
Oral reading		
	Kanji words	5/5
	Hiragana	10/10
	Hiragana words	5/5
	Short Sentences	5/5

Table 2 MT's results in the Standard Language Test of Aphasia (SLTA) (Continued)

Type	Tasks	Scores (March 5, 1996)
Reading comprehension	Kanji words	10/10
	Hiragana words	10/10
	Short sentences	10/10
	Written commands	9/10
Spontaneous writing	Writ. Naming (Kanji words)	4/5
	Writ. Naming (Kana words)	4/5
	Narrative Writing	6/6
	Dictation (Kana)	10/10
	Dictation (Kanji words)	4/5
	Dictation (Kana Words)	5/5
	Dictation (Short Sentences)	5/5
Arithmetic		16/20

However, at the time of the following testing, she showed some paralexias of postpositional particles in more complex sentences in newspapers or magazines. When the examiner pointed out these paralexias, she could correct them. Her principal complaint concerned her difficulties in reading Hiragana scripts because they are so cursive. At the word level, she revealed no deficits in any parts of speech in reading. There was no clear dissociation between oral reading and comprehension deficits. Mild anomic aphasia had disappeared at the time of the following tests.

With writing, she had no problem copying Kanji and Kana and demonstrated paragraphia in Kanji dictation, but no deficits in Hiragana two months after surgery. During subsequent tests, she sometimes showed paragraphia in Kanji, though she had no problem at the SLTA level (see Table 2). She claimed that she could not sometimes remember Kanji. Often, she could not even write one-letter Kanji learned at lower grade in elementary school. When a part of the Kanji was given, she could remember the whole and often wrote it.

CT scan demonstrated the left parietal cortical and subcortical lesions (see Figure. 1). Mini Mental State Examination (MMSE) score was 27 (forward digit span 4).

Experiment 1. Sequential letter matching task

We explored the relationship between visual and phonological processings of Hiragana and

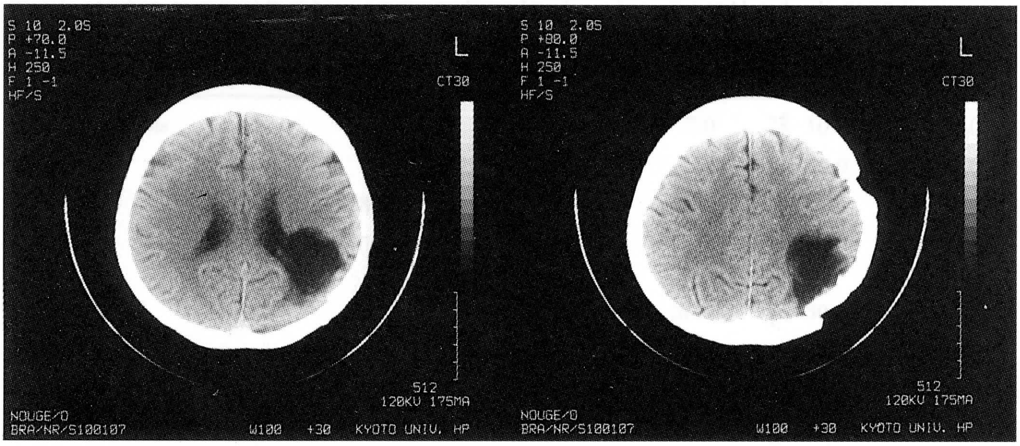

Figure 1. CT scan of MT (July 25, 1996) demonstrated a low density area in the left parietal cortical and subcortical region.

Katakana characters. In this task, subjects were asked to decide whether two letters had the 'same' name. When the ISI of two letters is less than 1.5～2 sec, the reaction time (RT) of physical identity pairs (e.g. AA) is much faster than that of nominal identity pairs (e.g. aA). As time passes, the relative advantage of the physical match is lost (Boles & Eveland, 1983; Kroll & Parks, 1978; Posner & Keele, 1967; Posner & Mirchell, 1967; Posner, Boies, Eichelmar, & Taylor, 1969; Proctor, 1981; Walker, 1981). In the present study, upper- and lower-case of Alphabets were replaced with Hiragana and Katakana scripts. In addition to investigating the relationship between the visual and nominal codings, we examined the influence of ISI conditions of letter pairs on Hiragana and Katakana processing.

Method

Subjects

In addition to MT, six right-handed control subjects, three males and three females, were also run in this study. Their mean age was 59.

Materials

Stimuli for this task were the pairs of Hiragana and Katakana letters in Table 3. They were selected because of the visual dissimilarity of their Hiragana and Katakana forms. Subjects had learned all stimuli used in the present study by the end of the first year in elementary school. Four lists of 80 trials consisted of 40 'same' and 40 'different' pairs. Of the 40 same pairs, 20 were physically identical, and were divided equally into Hiragana-Hiragana and Katakana-Katakana pairs (e.g., おお or オオ : H-H, K-K pairs, respectively). Twenty had the same identity, but were presented in different scripts (phonologically 'same' pairs), that is, Hiragana-Katakana, Katakana-Hiragana pairs (e.g., おオ or オお : H-K, K-H pairs, respectively). The 40 'different' pairs were constructed by pairing each Hiragana and Katakana letter (e.g., いお, いオ, イお, イオ). Letter pairs were presented in random order in each of the lists.

Table 3 Ten Hiragana and ten Katakana letters were used in the present study

Hiragana	Katakana	Pronunciation
お	オ	[o]
い	イ	[i]
こ	コ	[ko]
し	シ	[shi]
つ	ツ	[tsu]
た	タ	[ta]
ね	ネ	[ne]
ま	マ	[má]
め	メ	[me]
ゆ	ユ	[yu]

Procedure

The experiment was run on a computer with a white monochrome monitor. Four values for the ISI were chosen, 0, 200, 800 and 1500 msec, and a list of 80 trials was undertaken for each of these. Each letter subtended $2.6^\circ \times 2.6^\circ$ of visual angle. Each list was divided into two blocks. Before each block, a practice list containing 20 trials was run. These blocks were performed in random order.

Each trial began with the appearance of a fixation (+) in the center of the screen for 1000 msec, followed by a 500 msec blank interval. Then the first pair member appeared centrally for a duration of 100 msec and was covered by a random pattern mask for 30 msec, followed after an ISI of 0, 200, 800 or 1500 msec by a 100 msec presentation of the second pair member in the center. Then, the random pattern mask was displayed for 30 msec.

Each subject sat in front of a CRT screen and was supplied with two keys, mounted side-by-side, and was instructed to press the left hand key when the letters had the same name, and the right hand key when they were different. Control subjects performed the tests in one day, but MT did so on two separate days to avoid fatigue.

Results

The RT data of 'same' responses are presented in Figure.2 and the error data in Table 4. MT's reaction time and error data were analyzed separately from those of the controls in 2-way analysis of variance (ANOVA) with pair type (H-H, K-K, H-K, K-H), ISI (0, 200, 800, 1500 msec). They were supplemented by planned comparison of the H-H, K-K, H-K, and K-H conditions at each level of ISI for the RT results to examine the relationships of the pair types at each level of ISI s.

Table 4 Error rates (%) observed in each ISI and pair type condition

Subjects	ISI	H-H	K-K	H-K	K-H
Controls	0	12.0	7.0	10.0	15.0
	200	0.0	0.0	5.0	10.0
	800	7.0	3.0	7.0	5.0
	1500	3.0	7.0	10.0	7.0
MT	0	0.0	30.0	30.0	40.0
	200	0.0	0.0	40.0	40.0
	800	0.0	10.0	10.0	20.0
	1500	0.0	10.0	50.0	40.0

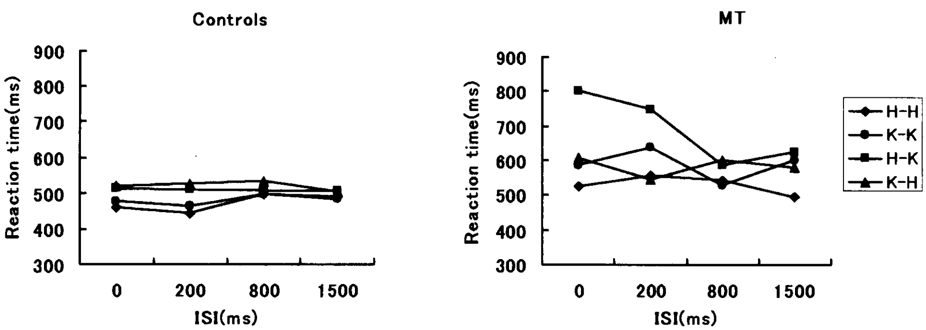

Figure 2. Mean RTs observed in the Control subjects and MT------Pair-type conditions: diamonds = H-H; circles = K-K; squares = H-K; triangles = K-H.

Controls

RT. The analysis revealed the pair type main effect to be significant (F (3, 15) = 7.28, $p < 0.01$), but the main effect of ISI and the pair type × ISI interaction did not differ significantly (F (3, 15) = 0.64, p = 0.60; F (9, 45) = 1.50, p = 0.18 respectively). Further analyses (Tukey's test) of the pair type conditions revealed the K-H condition RT was longer than that of the H-H, K-K conditions ($p < 0.01$) and the responses to the H-K pair were slower than those of only the H-H pair. The planned comparison showed that the H-K, K-H condition differed from the H-H, K-K conditions at ISI = 0, 200 ms (see Table 4). At ISI = 800, 1500 ms, there were no significant differences under any conditions ($p > 0.1$).

Errors. From the analysis, the main effect of ISI was significant (F (3, 15) = 3.97, $p <$ 0.05), though the pair type main effect and the pair type × ISI interaction were not significant (F (3, 15) = 1.84, p = 0.18 ; F (9, 45) = 1.28, p = 0.27 respectively). Tukey's test for ISI showed errors in the 0 msec condition were greater than those in the 200 msec condition ($p <$ 0.01).

MT

RT. The analysis showed the pair type main effect to be significant ($F(3, 112) = 4.17$, $p < 0.01$), but the main effect of ISI and the pair type × ISI interaction did not differ significantly ($F(3, 112) = 1.06$, $p = 0.37$; $F(9, 112) = 0.75$, $p = 0.67$). From the analyses (Tukey's test) of pair type conditions, the H-K condition RT was longer than that of the H-H conditions ($p < 0.01$). The planned comparison revealed that the H-K condition differed from the H-H, K-K, K-H conditions at ISI = 0, and 200 ms as shown in Table 5. At ISI = 800, 1500 ms, no pairs differed ($p > 0.1$).

Table 5 Planned comparisons of pair-type conditions (H-H, K-K, H-K, K-H) in Controls and MT at ISI = 0 ms (In parentheses ISI = 200 ms)
Controls: the upper triangle; MT: lower triangle

	H-H	K-K	H-K	K-H
H-H		n.s. (n.s.)	**(**)	**(**)
K-K	n.s. (n.s.)		*(*)	*(**)
H-K	**(*)	*(n.s.)		n.s. (n.s.)
K-H	n.s. (n.s.)	n.s. (n.s.)	$p = 0.05$ (0.06)	

*= $p < 0.05$; **= $p < 0.01$.

Errors. From the analysis, the main effect of pair type was significant ($F(3, 9) = 7.10$, $p < 0.05$), though the ISI main effect was not significant ($F(3, 9) = 1.95$, $p = 0.19$). Tukey's tests on pair types revealed errors in the H-H condition were less than those of the H-K and K-H conditions ($p < 0.05$).

Discussion

From this experiment, the following results were found. 1) In control subjects, the RTs of phonologically 'same' pairs were significantly shorter than those of physically 'same' pairs. 2) Conversely, MT showed an RT delay in the H-K condition (one of the phonologically 'same' conditions) under ISI = 0, 200 ms conditions. For MT, the phonological processing of Hiragana was difficult, especially with short presentations of letters. When two letters were presented serially, she needed more time to process Hiragana and Katakana in parallel, because of the retroactive (Katakana to Hiragana) or proactive (Hiragana to Katakana) phonological interference in the H-K condition. Therefore, it is necessary to test each single letter's phonological processing.

Experiment 2. Reading letter aloud task

The reading times for each letter were measured to examine whether there was a delay in the reading time in Hiragana, even in the one-letter condition, or not. We also investigated the effect of manipulated exposure durations on reading time in the difference between Hiragana and Katakana, and the relationship between her visual and phonological processings of these letters.

Method

Subjects

In addition to MT, two right-handed control subjects, a male and a female, were also tested in this study. Their mean age was 59.5.

Materials

Stimuli were 46 Hiragana and 46 Katakana scripts. They were divided into five lists of 20 trials (one list contained 12 trials) for each script.

Procedure

The experiment was run on a computer. The duration of stimuli was manipulated under two conditions, limited exposure duration (100 ms) and no-limited exposure duration. Each letter subtended at a $2.6^\circ \times 2.6^\circ$ visual angle. Each list was divided into two blocks. Before each block, a practice list containing 20 trials was run. Half lists were administered in limited exposure duration first, and the rest were in non-limited exposure duration first. These lists were presented in random order.

Each trial began with the appearance of a fixation (+) in the center of the screen for 1000 msec, followed by a 500 msec blank interval. Then, one letter appeared centrally for a duration of 100 msec and was covered by a random pattern mask for 30 msec in the limited exposure duration. In the non-limited exposure duration condition, a letter was presented until subjects responded to it. Subjects were instructed to read the letter aloud as quickly as possible.

Results and Discussion

The reading time data for correct responses are presented in Figure. 3. For error data of MT and controls there were no differences between Hiragana and Katakana under either presentation conditions. MT's and control's RT data were separately analyzed in T-test under their respective exposure durations.

Controls

In both exposure duration conditions, the differences in their reading times for Hiragana and Katakana conditions were not significant ($z = -1.34$, $p = 0.18$; $z = -0.45$, $p = 0.66$, respectively), though their Katakana responses were slower than those for Hiragana. Their overall accuracies were 96.7% and 98.9% under limited and non-limited exposure durations, respectively.

MT

In the 100 msec condition, the difference in reading time in the Hiragana and Katakana

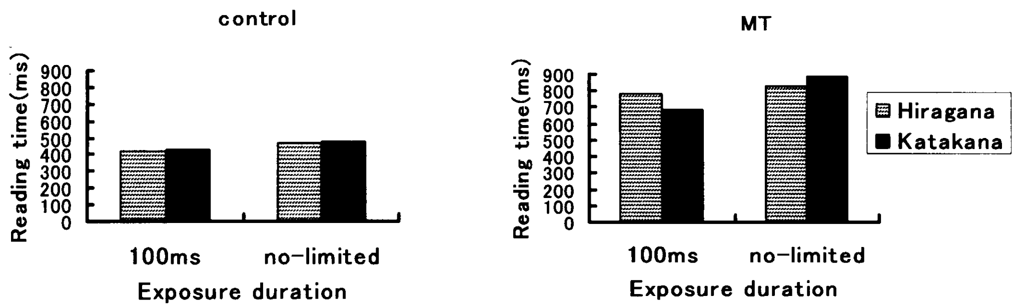

Figure 3. Reading time data for correct responses

conditions was marginally significant (z = -1.78, p = 0.08). MT's responses to Hiragana were slower than those for Katakana. Under the non-limited exposure duration, however, the reading times of Hiragana were shorter than those of Katakana (z = -1.73, p = 0.08). Sometimes, she made some reading errors in Hiragana, which were visually similar to the target (e.g. ぬ [nu] →め [me]). Her overall accuracies were 58.7% (limited exposure duration), and 91.3% (non-limited exposure duration).

At the one-letter level, controls showed no difference between Hiragana and Katakana processing. However, MT revealed a reading time delay in Hiragana only under the short exposure duration. From the result of Experiment 2, it is possible that her Hiragana reading difficulty was in the visual-phonological processing of letters under short presentation conditions.

General Discussion

In aphasic patients, Sasanuma et al. (1971) pointed out that in the visual recognition of words transcribed in Kana, in particular Hiragana, the transcriptions have to be processed by the phonological processor before the word as a lexical form is identified. They assumed that the Katakana word represents an intermediate case between the Kanji and Hiragana words. Hamanaka et al. (1980) also suggested similar findings from the results of reading comprehension of aphasics. The investigation of alexic patients makes it easier and clearer to assess patients with reading disturbances than that of aphasics. As for patients with alexia with agraphia having the left angular gyrus lesion, they usually show difficulties in reading Kana, though their Kanji reading deficits are mild, as we have already seen (Iwata, 1984; Yamadori, 1975, 1979). Yamadori (1979) suggested that reading of letters is more affected than that of words, and that this difficulty has relevance to the deficit of transcoding from graphemes to phonemes. However, it has not yet been clarified whether these patients process Hiragana and Katakana differently. The case presented by Yamadori (1975) showed no substantial differences between Hiragana and Katakana. However, Iwata (1987) argued that reading deficits in alexia with agraphia were in Kana, especially in Hiragana.

In Experiment 1, why did MT show a delay in RT in only the H-K condition at ISI = 0, and 200 msec? If Hiragana were processed more phonologically than Katakana, even at the letter level, MT would have difficulty in the processing of Hiragana due to phonological deficits. As her reading problem had disappeared, only with less than 1 sec ISI, her deficits were residual in the delay in Hiragana phonological processing especially. She may also be susceptible to some sort of interference from subsequent homophonic Katakana. However, in Experiment 2, even at the single letter level, MT revealed an RT delay in Hiragana under the short exposure duration. In the non-limited exposure duration, however, MT's reading time delay in Katakana was like that of the controls. Therefore, MT's Hiragana processing deficit was in rapid visual-phonological coding. That is, when Hiragana was presented quickly, it was difficult for her to process it phonologically.

She showed impairment in nonword reading under measuring reading thresholds and Hiragana phonological processing deficits in the present study. MT's reading difficulty under the short exposure duration was similar to that of phonological alexia (Beauvois & Derouesne, 1979; Derouesne & Beauvois, 1979, 1985). Some studies have been done on Japanese phonological alexia (Patterson, Suzuki & Wydell, 1996; Sasanuma, Patterson, & Ito, 1996). Though Sasanuma et al. (1996) showed no difference between Hiragana and Katakana script reading, their main subject was lexical processing, not letter processing. However, MT had no nonword reading difficulty when the reading time was unlimited. Even if phonological alexic patients' impairments recover, these may be residual in particular situations, such as short presentation conditions.

In Experiment 1, MT showed many more errors in phonologically 'same' conditions compared to only H-H pairs. From this, we cannot say for certain whether the H-H, K-K conditions were processed equally. However, it is clear that the visual matching of Hiragana scripts was much better than their phonological matching. Proctor (1981) found that sequential name matches could be performed in parallel and that subjects adopt the strategy of first matching in parallel at the physical-code level, and then serially comparing physically mismatching letter pairs at the name-code level. Taking account of this finding, it is thought that MT's deficit was not in parallel processing of physical code, but in serially comparing the physical code with the phonetic code in the case of Hiragana processing.

For normal subjects, some studies have argued that Hiragana and Katakana words may have different lexical representations (Hatta & Ogawa, 1983; Hatta, 1984; Hatta, et al., 1984; Yamadori, 1975). Even in this study on letters, the controls' K-H condition RTs were longer than those of physically 'same' pairs. We cannot confirm why there was no significant difference between the K-H and H-K pairs. However, when Katakana was presented first and was temporally close to the second stimulus, its rapid phonological processing was difficult, in contrast to MT who revealed a Hiragana processing deficit. If Hiragana scripts are easier and more necessary to process phonologically than Katakana in normal subjects, it is likely that MT would show an RT delay in the H-K condition in the phonological letter matching task. Even at the one-letter level, normal subjects read Hiragana scripts faster than Katakana characters though the difference in the reading time of these scripts was not significant. This is the same result as Sakuma et al. (1997). It is possible that Hiragana phonological processing is done more automatically than Katakana for normal subjects. However, it could be that the cursive Hiragana characters are visually and phonologically more taxing for alexic patients like MT than Katakana characters, which consist of straight and distinct lines.

In conclusion, her reading problems were residual in visual-phonological processing, especially in the rapid processing of Hiragana characters, even if the reading symptoms were mitigated. For Japanese, it is possible that there are different phonological processing mechanisms between Hiragana and Katakana, even in Kana scripts, which are revealed only in patients with visual-phonological coding deficits.

References

Beauvois, M.F. & Derouesne, J. (1979). Phonological alexia: three dissociations. *Journal of Neurology, Neurosurgery, and Psychiatry*, **42**, 1115-1124.

Besner, D. and 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.

Boles, D.B. and Eveland, D.C. (1983). Visual and phonetic codes and the process of generation in letter matching. *Journal of Experimental Psychology: Human Perception and Performance*, **9**, 657-673.

Derouesne, J. and Beauvois, M.F. (1979). Phonological processing in reading: data from alexia. *Journal of Neurology, Neurosurgery, and Psychiatry*, **42**, 1125-1132.

Derouesne, J. and Beauvois, M.F. (1985). The 'phonemic' stage in the non-lexical reading process: Evidence from a case of phonological alexia. In K.E. Patterson, C. Marshall, and M. Coltheart (Eds.), *Surface Dyslexia*. London: Lawrence Erlbaum Associates, pp. 399-457.

Hamanaka, T., Kato, N., Ohashi, H., Ohigashi, Y., Tomita, A., Hadano, K. and Asano, K. (1980). Kanji versus Kana problem in aphasiology. *Sinkeinaika*, **13**, 213-221. (in Japanese)

Hatta, T. and Ogawa, T. (1983). Hiragana and Katakana in Japanese orthography and lexical representation. *Language Sciences*, **5**, 185-196.

Hatta, T. (1984). Reading processes in Japanese: Do the Japanese have script-specific mechanisms? *Language Sciences*, **7**, 355-363.

Hatta, T., Katoh, H. and Kirsner, K. (1984). Lexical representation of foreign loan words in Japanese learners among native readers of English. *Psychologia*, **27**, 237-243.

Hirose, T. (1984). The effect of script frequency on semantic processing of Kanji and Kana words (in Japanese). *The Japanese Journal of Psychology*, **55**, 173-176.

Hirose, T. (1985). The effect of orthographic familiarity on word recognition. *The Japanese Journal of Psychology*, **56**, 44-47. (in Japanese)

Iwata, M. (1984). Kanji versus Kana: Neuropsychological correlates of the Japanese writing system. *Trends in Neuroscience*, **7**, 290-293.

Iwata, M. (1987). *Nou to communication*. Tokyo: Asakurashoten. (in Japanese)

Komatsu, S. and Naito, M. (1992). Repetition priming with Japanese kana scripts in word-fragment completion. *Memory & Cognition*, **20**, 160-170.

Kroll, N.E. and Parks, T.E. (1978). Interference with short-term visual memory produced by concurrent central processing. *Journal of Experimental Psychology: Human Learning and Memory*, **4**, 111-120.

Matsunaga, A. and Ohigashi, Y. (1998). Abnormal thresholds for reading in two mitigated alexic patients. *Japanese Journal of Neuropsychology*, **14**, 170-178. (in Japanese)

Ohta, Y. and Koyabu, S. (1970). A clinical study on constructional agraphia in Japanese language. *Seishinigaku*, **12**, 51-56. (in Japanese)

Patterson, K., Suzuki, T., and Wydell, T.N. (1996). Interpreting a case of Japanese Phonological alexia: the key is in phonology. *Cognitive Neuropsychology*, **13**, 803-822.

Posner, M.I. and Keele, S.W. (1967). Decay of visual information from a single letter. *Science*, **158**, 137-139.

Posner, M.I. and Mitchell, R.F. (1967). Chronometric analysis of classification. *Psychological Review*, **74**, 392-409.

Posner, M.I., Boies, S.J., Eichelman, W.H. and Taylor, R.L. (1969). Retention of visual and name codes of single letters *Journal of Experimental Psychology Monograph*, **79**, 1-16.

Proctor, R.W. (1981). A unified theory for matching-task phenomena. *Psychological Review*, **88**, 291-326.

Reuter-Lorenz, P.A. and Brunn, J.L. (1990).A prelexical basis for letter-by-letter reading: A case study. *Cognitive Neuropsychology*, **7**, 1-20.

Sakuma, N., Fushimi, T., and Tatsumi, I. (1997). Measurement of naming latency of kana characters and words based on the speech wave analysis: Manner of articulation of a word-initial phoneme considerably affects naming latency. *Japanese Journal of Neuropsychology*, **13**, 126-136. (in Japanese)

Sasanuma, S. and Fujimura, O. (1971). Selective impairment of phonetic and non-phonetic transcription of words in Japanese aphasic patients: Kana versus Kanji in visual recognition and writing. *Cortex*, **7**, 1-18.

Sasanuma, S. (1974). Kanji versus kana processing in alexia with transient agraphia: A case report. *Cortex*, **10**, 89-97.

Sasanuma, S. (1980). Acquired dyslexia in Japanese: Clinical features and underlying mechanisms. In M. Coltheart, K.E. Patterson, and J.C. Marshall (Eds.), *Deep Dyslexia*, London: Routledge and Kegan Paul, pp. 48-90.

Sasanuma, S., Ito, H., Patterson, K., and Ito, T. (1996). Phonological alexia in Japanese: A case study. *Cognitive Neuropsychology*, **13**, 823-848.

Usui, N. (1998). On the role of holistic processing in the recognition of Japanese kana words. *The Japanese Journal of Psychology*, **69**, 105-112. (in Japanese)

Walker, P. (1981). Short-term visual memory: The importance of the spatial and temporal separation of successive stimuli. *Quarterly Journal of Experimental Psychology*, **30**, 665-679.

Yamadori, A. (1975). Ideogram reading in Alexia. *Brain*, **98**, 231-238.

Yamadori, A. (1979). Alexia with agraphia. *Shinkeinaika*, **10**, 428-436. (in Japanese)

Yamadori, A. (1980). Cerebral laterality and Kanji-kana processing. *Advances in Neurological Sciences*, **24**, 100-108. (in Japanese)

Yokoyama, S. (1991). The effect of orthographic familiarity on recall of stimulus items read aloud. *The Japanese Journal of Psychology*, **62**, 195-199. (in Japanese)

(Received November 7, 2006)
(Accepted December 26, 2006)