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Kana and Kanji Processing in Patients with Unilateral Brain Damage

Akira OTSUKA* and Mutsuo SHIMADA**

SUMMARY

Patients with left-hemisphere damage (LHD) or right hemisphere damage (RHD) were administered two word processing tasks (naming and matching word to drawing) in which stimuli were written in Kana and Kanji characters, and presented in the right or left visual field. In the correct responses of LHD, there were no significant differences between characters, between tasks, nor between visual fields. But in those of RHD, performance on Kanji characters was inferior to that on Kana and the left visual field performance was inferior to that on the right. The performances of LHD were generally inferior to those of RHD. These results were interpreted as evidence for left hemisphere dominance in the processing of both Kana and Kanji characters, while the right hemisphere being able to process the Kanji characters some degree.

INTRODUCTION

The Japanese writing system is uniqe in two types of characters: Kana*** and Kanji are used in combination. Kana characters are syllabaries each with a one-to one correspondence with a specific mora****. Kanji characters, on the other hand, are morphemographies*****, representing meaning as well as phonetic values (11, 13). It is well-known that Japanese aphasic patients show various types of dissociation between the ability to process Kana and Kanji. Usually Kana characters are more impaired than Kanji characters. This interesting phenomenon has been reported in many studies, and various hypotheses have been proposed to explain it (2, 15, 20, 25).

Recent studies discuss this problem from standpoint of functional hemisphere specialization (26, 27). According to Shimada (26), Kana characters are

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* Akira OTSUKA (大塚　晃): Ijinkai Takeda Hospital/Kyoto. A member of aphasia group in Kyoto University.

** Mutsuo SHIMADA (島田睦雄): National Institute of Employment and Vocational Research/TOKYO.

*** Kana characters are divided two types, i. e., Hiragana and Katakana. In this study the term, Kana character used as the sense of Hiragana.

**** Mora is the minimum unit of the utterance.

***** Morphemography correspondes to morpheme in speech, and is the character representing the minimum meaningful linguistic unit.

phonemic symbols, thus their processing requires the transformation of a grapheme to a corresponding phoneme. However, Kanji characters are both phonemic and logographic symbols. Thus their processing does not always require a grapheme-to-phoneme conversion. That is one can process Kanji characters directly via their word form, without any phonological mediation. As is well-known, the dominant hemisphere (usually the left in right-handed persons) processes such as the grapheme-phoneme conversion, and the non-dominant hemisphere (usually the right in right-handed persons) possesses the visual pattern recognition function. Thus, Kana characters are processed mainly by the left hemisphere, but Kanji characters may be processed right hemisphere as well as left one. In aphasic patients, who have usually left hemisphere lesion, Kana processing is strongly impaired due te the left hemisphere lesions. On the other hand, Kanji processing may be preserved or less impaired than that of Kana because of the compensation of the right hemisphere. The results of Shimada's experiment (26) supported this hypothesis. He found that normal persons showed right visual field superiority in Kana processing but showed no visual field differences in Kanji processing.

Some studies concerning functional hemisphere differences for Kana and Kanji processing have been reported (6, 8, 10, 24, 28). The results are not always consisted with those of Shimada's experiment (26). In the case of Kana processing, right visual field (RVF) superiority is typically found in normal persons (6, 8, 10, 24, 28) and in patients who had received a partial commissurotomy (29, 31). However, with regard to Kanji processing, Hatta (8) and Sasanuma et al. (24) have reported a left visual field (LVF) superiority in normal persons. But Shimizu (28) found no visual field differences, and Sugishita et al. (29) reported that performance in the RVF was superior to that in LVF for both Kana and Kanji characters in the oral reading and comprehension of partial commissurotomized patients. Watanabe et al. (31) also reported similar results in patients who had received partial commissurotomy.

Based on the above-mentioned research, it can be concluded that there is a consistent RVF superiority for Kana processing. However the direction of the visual field superiority of Kanji processing alters according to each study and no consistency is seen.

There are interpretative difficulties in previous studies concerning Kanji processing. Many studies seem to presuppose that any visual field difference obtained from normal persons or patients with commissurotomy are directly related functional hemisphere specialization. Is it really so? The cerebral hemispheres are themselves linked by a number of nerve tracts or commissures in normal person. The patients of Sugishita et al. (29) and Watanabe et al. (31) were sectioned only the splenium of the corpus callosum and the greater part of their commissure fibers remained intact. In such cases, it is very probable that the information from the two visual hemifields is integrated by means of the cerebral commissures. However, there are few studies analyzing the level or levels of information processing at which inter-hemispheric coordination and integration might take place. Given the lack of understanding of the function of the cerebral commissure, data obtained normal persons or partially commissurotomized patients are at present limited to showing only to which of the cerebral hemisphere stimuli were initially projected, and the interpretation of observed laterality effects is correspondingly difficult (3, 27). So, it is need to study the functional hemisphere specialization of Kanji processing by the method that is different from that of previous studies.

The concept of functional hemisphere specialization arose originally from studies of patients with unilateral brain damaged (9). Although lateralization of impairment is not always equal to lateralization of function, it can give us useful information to investigate the effects of unilateral hemisphere damage on Kana and Kanji processing. However there are very few such studies. The purpose of this study is to investigate Kana and Kanji processing in patients with unilatarel brain damage from viewpoint of functional hemisphere specialization.

METHOD

Subject: 36 patients with unilateral brain damage served as the subjects of this study. Fifteen of them had brain damage confined to the left hemisphere (LHDs) and 21 had damage in the right hemisphere (RHDs) as determined by clinical findings and computerized tomography. All subjects were right-handed as determined by self-report. Among the LHDs, 12 were male and 3 were female. Among the RHDs, 19 were male and 2 were female. The mean age of LHDs was 59.0 years with an age range of 34 to 77 years. The mean age of RHDs was 54.4 years with an age range of 19 to 72 years. The mean duration of illness in LHDs and RHDs was 7.8 and 7.0 months, with a range 2 to 44 and 1 to 33 months respectively. Differences of age and duration of illness were not significant. As for etiology, 35 had been suffered from cerebrovascular accidents and one subject had brain trauma. Six subjects of the LHDs were clinically aphasic while no subject among the RHDs was aphasic. 4 of aphasic were Broca's aphasia, one was Wernicke's aphasia and one was amnesic aphasia. No subject had a visual field defect and any other neuropsychological disorder (agnosia, apraxia, alexia, agraphia or unilateral spatial neglect).

The topography of brain damage was determined from the results of tomography, based on the anatomical relationships published in Matsui and Hirano's atlas (18). Among RHDs, 1 patient had exclusively frontal damage, 2 exclusively temporal, 4 exclusively parietal, 6 fronto-parietal, 2 fronto-temporal, 4 temporo-parietal and 2 fronto-temporo-parietal. Among LHDs, there were 2 with exclusively frontal damage, 1 exclusively temporal, 3 exclusively parietal, 4 fronto-parietal and 5 temporo-parietal. Among aphasics, 1 had exclusively temporal damage, 4 front-parietal and 1 front-temporo-parietal.

Table 1. Kana and Kanji stimuli

Kana word	やま	いぬ	みず	いえ	ほん
Kanji word	山	犬	水	家	本
Pronunciation	(yama)	(inu)	(mizu)	(ie)	(hon)
Meaning in English	mountain	dog	water	house	book
Kana word	でんわ	きもの	ぼうし	きって	とけい
Kanji word	電話	着物	帽子	切手	時計
Pronunciation	(denwa)	(kimono)	(boshi)	(kitte)	(tokei)
Meaning in English	telephone	kimono	hat	stamp	clock

Apparatus and stimuli: A three channel tachistoscope which consisted of a Kodak Ectagraphic projecter mounted electric shutter and an optical wedge were used to present stimuli. The stimuli used this study are shown in Table 1. These consisted of ten real words printed both in Kana and Kanji characters. Those words were selected out from the reading test of Standard Language Test of Aphasia (SLTA) which is used as a screening test for aphasia most widely in Japan. The stimuli were exposed behind into a trunslucent screen placed 100 cm in front of the subject at eye-level. Each of the stimuli appeared 3.1° to the right or left of the center of screen and subtented a visual angle of 1.1° (words consisting of one character) or 3.5° (words consisting of two or three characters) vertically and 1.1° horizontally. The luminance of the stimuli was 32 NIT.

Procedure: The exposure duration of the stimulus was determined individually for each subject by means of the method of limits in a such a way that the subject was required to discriminate the direction of a break in a Landort ring (with a diameter of 1.1°) presented in a center of screen. The exposure duration for which subject could discriminate 7/8 correctly was used in stimulus presentation. The exposure duration thus obtained ranged from 100-180msec.

Subjects sat at a table and were asked to fix on a small red circle presented in the center of the screen. They were asked to engage in the following two tasks.

1. Naming : Subjects were required to read aloud the word that was presented in either the left or right visual field.

2. Recognition : matching words to drawings : A single word was presented in either the left or right of visual field and subjects were required to match it to the corresponding object drawing in a array of 15 drawings displayed on the table. Of 15 drawings, 10 had corresponding words, and 5 did not.

For each task, 10 of Kana and 10 of Kanji words were presented once in the right and left visual field. The order of stimulus presentation and visual fields were randomized in each task. The order of tasks was counterbalanced over subjects.

RESULTS

The exposure duration ranged from 100 to 140msec with the mean of 107msec in RHDs, and from 100 to 180msec with the mean of 122msec in LHDs. Since difference of exposure durations between RHDs and LHDs was not seen ($t=2.05$, $p>0.05$),the data of all subjects were used in combination regardless of exposure durations.

Table 2. Mean percentages of correct responses in RHDs

	Naming		Recognition	
	RVF	LVF	RVF	LVF
Kana				
Mean	76.7	65.7	82.4	71.0
s. d.	21.0	27.7	18.0	24.5
Kanji				
Mean	73.3	54.3	76.7	60.1
s. d.	27.7	22.8	20.8	21.4

Table 3. Mean percentages of correct responses in LHDs

	Naming		Recognition	
	RVF	LVF	RVF	LVF
Kana				
Mean	56.0	58.0	52.0	50.0
s. d.	31.8	30.8	33.5	32.0
Kanji				
Mean	54.7	54.4	56.0	57.3
s. d.	29.2	33.5	32.0	27.4

Table 2 shows the mean percentages and standard deviations of correct responses in RHDs, and Table 3 shows the mean percentages and standard deviations in LHDs.

A four way analysis of variance with one between group factor (Laterality of lesion) and three within group factors (Task, Visual field and Character) was carried out. The group factor indicated a non-significant trend ($F=3.52$, $df=1,34$, $0.05<p<0.10$) showing performances of LHDs were generally inferior to that of RHDs. The factor of visual field was significant ($F=9.25$, $df=1,3$ $p<0.005$); namely the performance of RVF was superior to that of LVF. The interaction between group and visual field was significant ($F=13.37$, $df=1,34$, $p<0.001$). This indicates that RVF superiority was seen only in RHDs. Other main effects and interactions were all not significant.

Three-way analyses of variance with one between group factor (Laterality of lesion) and two within group factors (Visual field and Character) were carried out separately for naming and recognition. In naming, the factor of visual field was significant ($F=9.03$, $df=1,34$, $p<0.01$); namely, the RVF was superior to the LVF. The interaction between group and visual field was significant ($F=11.79$, $df=1,34$, $p<0.01$). This indicates the above-mentioned RVF superiority was due to impairment of the LVF performance in RHDs. Other main effects and interactions were not significant. In recognition, the factor of group was significant ($F=4.79$, $df=1,34$, $p<0.05$); namely the RHDs was superior to the LHDs. The factor of visual field and interaction between group and visual field were significant (the former: $F=6.15$, $df=1,34$, $p<0.05$; the latter: $F=9.91$, $df=1,34$, $p<0.01$) indicating that performance of the RHDs was more impaired in the LVF than in the RVF. Other main effect and interaction were not significant.

A three-way analysis of variance with Task, Visual field, and Character as factors was carried out separately for RHDs and LHDs. In the RHDs, the factor of character was found to be significant ($F=7.59$, $df=1,20$, $p<0.05$); namely, Kana processing was superior to Kanji processing. The factor of visual field was also significant ($F=21.29$, $df=1,20$, $p<0.001$); that is, the RVF was superior than the LVF. The factor of task was not significant. The interaction between visual field and character indicated a non-significant trend ($F=4.19$, $df=1,20$, $0.05<p<0.10$),showing Kanji characters were more impaired in the LVF than the RVF. Other interactions were not significant. There was no significant main effect nor any significant interaction in LHDs.

Discussion

The results of this study can be summarized as follows:

1. The LHDs were more impaired than the RHDs in both Kanji and Kana processing in recognition task. Such impairment of processing in the LHDs was also seen in naming task although the difference was not statistically significant.
2. In RHDs, Kanji processing was more impaired than Kana processing, especially in the LVF. Differences between tasks were not seen.
3. In LHDs, no difference due to task, character or visual field was found.

These results seem to indicate that the left hemisphere is generally dominant for word processing regardless the nature of the character or type of processing. Before we reach this conclusion, however, some other possibilities should be considered. One of them is that above-mentioned impairment in LHDs is due to not the left hemisphere brain damage itself but aphasia, agnosia or other neuropsychological disorders associated left hemisphere damage. We compared performances of LHDs with aphasia with those of LHDs without aphasia using a three-way analysis of variance with Group, Character, and Visual field as factors. The group factor was not significant ($F=1.04$, $df=1,13$, $p>0.05$) : namely presence of aphasia had not any effect on performances of LHDs. As already mentioned, there was not any other neuropsychological disorder in both LHDs and RHDs. It is, therefore, safe to say that left hemisphere damage itself impaired Kana and Kanji processings.

The another possibility is that the result may arise from one or two words with particular characteristics, and may not generalizable to the population of Kana and Kanji words. One method of a solution to this problem is to carry out a variance of analysis using words as subjects. A three-way analysis of variance with Group, Word and Visual field as factors was carried out. The intaraction between word and group was not significant ($F=0.85$, $df=9,30$, $p>0.05$) and a three-way interaction among word, group and task was not also significant ($F=1.88$, $df=9,30$, $p>0.05$). It can be said that the impairement in LHDs was not brought about by a specific word or a group of words.

The evidence here for left hemisphere dominance for Kana processing is consistent with results from previous studies using normal persons (6, 10, 24, 26, 27) or patients with partial commissurotomization as subjects (29, 31) and also agrees with foreign studies have revealed a RVF superiority in the processing of alphabetical material (19, 22).

The results for Kanji processing coincide with the results of studies of patients with partial commissurotomization (29, 21) but is different from studies using normal persons (6, 10, 24, 28). Studies showing the LVF superiority of Kanji processing have serious methodological problems. Experiments of Hatta (8) and Sasanuma, et al. (24), for example, were conducted by presenting only Kanji characters. It is very possible that subjects depend only on the visual configuration of stimuli for processing them under such conditions (As each Kanji character has several phonemic counterparts, different Kanji characters often have same reading. Therefore, Kanji processing is easier in cases depending on the visual configuration than those depending on the phonemic cue if only Kanji characters are presented). Kanji characters have more complicated configurations in comparison with Kana characters and are mutually very similar. It seems that the processing of Kanji characters is one of complicated visual patterns. Since the right hemisphere is dominant for visuo-spatial information processing (3, 9), it is very reasonable that the LVF is superior to the RVF for Kanji processing under such conditions. Processing of Indo-European language is usually superior in the RVF (3, 19, 22). But it is recognized that if the physical natures of stimuli became more complicated (for example, reduction of exposure duration, reduction of luminance, etc), the superior visual field shifts from right to left (4, 14, 21). These facts indicate that the visual field differences of a specific linguistic stimulus dependent not only on the linguistic properties of the stimulus but also on the it's physical properties. Hatta (8) and Sasanuma et al. (24) insisted that the LVF superiority of Kanji processing was caused by the linguistic properties of Kanji characters. However, it is more reasonable to think that such a phenomenon is caused by physical properties of Kanji characters. If so, it is not a unique phenomenon in Kanji characters but may be seen in Indo-European language as mentioned above. It can be concluded that the studies of Hatta (8) and Sasanuma et al. (24) were not an investigation of the functional hemisphere differences in Kanji processing but an investigation of visual pattern recognition using Kanji characters as a stimulus (27).

Thus, it is safe to say that the left hemisphere is dominant for the processing of both Kana and Kanji characters. However, there still remains one problem. That is whether the right hemisphere totally lacks the ability for Kana or Kanji processing, or whether it has such ability to some degree.

The performance of Kanji processing in the RHDs was inferior to that of Kana processing. Such difference was not seen in the LHDs. This indicates that damage of the right hemisphere can cause more impairment in Kanji processing in comparison with Kana processing. Does this fact mean a selective defect of Kanji processing or a general defect of visual pattern recognition? In order to clarify this point, performances of RHDs for Kanji words consisted of two characters were compared with those of words consisted of one character. If above-mentioned impairment of Kanji processing is due to the general defect of visual pattern recognition, words consisted two character (namely more complicated stimuli) should be more impaired. A three-way analysis of variance with Task, Number of characters and Visual field as factor was carried out. Factor of Number of characters was not significant ($F=0.37$, $df=1,8$, $p>0.05$). Although we can not exclude completely the possibility that impairment of Kanji processing in RHDs is related to the general defect of visual pattern recognition, it is more reasonable to think that such impairment suggests some contributions of the right hemisphere to Kanji processing.

Sakamoto (23) reported a case of alexia without agraphia about forty years ago. His patient had severe impairment of Kana processing in oral reading and comprehension but Kanji character processing was intact to some degree. Iwata (12) also recently reported a case of alexia without agraphia whose symptoms were very similar to those of Sakamoto's patient. Both patients had right homonyous hemianopsia. According to Geschwind (7), such a case had two lesions, one involving the left primary visual cortex and other destroying the corpus callosum. The lesion in the left visual area prevents visual stimuli entering the left hemisphere from reaching the angular gyrus which is necessary for reading, while visual stimuli which enter the right hemisphere are prevented from reaching the left hemisphere because of the destroying splenium of the corpus callosum. If this theory is correct, the residual reading ability of the patients with alexia without agraphia might very well originate in the right hemisphere. It appears to be possible that informations of Kanji characters are transfered from the right hemisphere to the left one via nonsplenial routes in cases of alexia without agraphia. Sakamoto and Iwata reported that their patients were able to comprehend the meaning of Kanji characters, but their ability to read aloud Kanji characters was very restricted. It is possible, but not probable that only semantic informations of Kanji characters can be transfer from the right hemisphere to the left one but phonemic informations of them can not. Thus, the preservation of reading ability for Kanji characters in cases of alexia without agraphia can be seen as evience that the right hemisphere can process Kanji characters. Yamadori (33, 34) suggest such a possibility based on a review of previous papers and his own experiences. The facts that Kanji processing is more impaired than Kana processing in RHDs and Kanji processing is preserved some degree in patients of alexia without agraphia are best explained by hypothesis that the right hemisphere possesses the ability for Kanji processing to some degree.

How does the right hemisphere process Kanji character? There are no data to answer this question directly, but some speculation may be possible from the previous related studies.

Recently some authors proposed various models of word information processing (1, 17, 30). Their common point is that there are at least two system concerning such processing. The first, tentatively labelled phonological processing, is specialized for application of the grapheme-phoneme transformation. The second, labelled semantic processing, serves to recognize single-morpheme words, enabling to the lexicon/semantic system. Those two systems seem to operate parallel to and independently of each other. The phonological processing is specialized in the left hemisphere. Concerning semantic processing, some authors suspected that it may operate in the right hemisphere. Zaidal (35, 36) and Levy (16) reported that the semantic processing abilities of right hemisphere was much better than previoslly supposed. Considering this research, it is suspected that the right hemisphere possesses the ability for semantic processing of Kanji characters, while it lacks the ability for phonological processing of them. This possibility was already pointed out by Coltheart (6). He reviewed a syndrome complex of 'deep dyslexia' including Japanese cases, and suggested that the right hemisphere could derive semantic information much more effectively from Kanji characters than from Kana characters. Sakamoto's (23) patient could comprehend the meaning of Kanji characters without having capability for oral reading. Such a phenomenon was observed in a patient of Iwata (12) and Yamadori (32). Sugishita et al. (29) reported that their patients's comprehension of Kanji characters was better than oral reading of them in the LVF. These facts suggest that Kanji characters may be processed semantically without adequate analysis of their phonemic values and that such processing operates in the right hemisphere.

The discussion above can be summarized as follows. The left hemisphere is dominant for processing of written materials in Japanese, Kana and Kanji, as well as Indo-European language. The right hemisphere is able to process Kanji characters to some degree by semantic processing.

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