RECOGNITION OF JAPANESE *KANJI* AND *HIRAKANA* IN THE LEFT AND RIGHT VISUAL FIELDS

TAKESHI HATTA¹

Osaka University of Education

Two experiments were conducted concerning recognition of verbal material in Japanese. In Experiment I, single *Kanji* and *Hirakana* (corresponding to the used *Kanji*) were presented tachistoscopically to the left or right visual field. *Kanji* was recognized more accurately in the left visual field while *Hirakana* was recognized better in the right visual field. In a second experiment, *Kanji* words and mixed words (*Kanji* were mixed with *Hirakana*) were presented to either the left or the right visual field. The results indicate that *Kanji* has properties which are different from the other types of verbal materials and the direction of laterality differences for *Kanji* depends upon very different types of brain processing. Furthermore the results suggest the possibility of cultural differences between Japanese and Westerners in hemispheric information processing systems.

Many tachistoscopic recognition experiments show a right visual field superiority for verbal materials and this has been interpreted in terms of functional hemispheric asymmetry (Mishkin & Forgay, 1953; Bryden & Rainey, 1963; Bryden, 1965; Kimura, 1966; Hatta, 1977a).

Several studies have reported on visual field differences with respect to verbal materials in Japanese orthography. Japanese orthography is peculiar in that three types of symbols, *Katakana*, *Hirakana*, and *Kanji* are used in combination. *Katakana* and *Hirakana* are phonetic symbols for syllables as are the letters of the European alphabet for consonants and for vowels. *Kanji* are essentially non-phonetic logographic symbols or ideographs. There are about ten thousand *Kanji* in Japanese orthography but the minimal set of 1850 *Kanji* is adopted for standard use by the Japanese Ministry of Education.

With regard to the recognition of Japanese verbal materials, Hirata and Osaka

(1967) reported that words in *Katakana* were recalled better in the right visual field than in the left visual field whether they were exposed unilaterally or bilaterally. Hatta (1976) also suggested a superior function of the left hemisphere for the perception of *Hirakana* letters in Japanese because the experimental condition where they were presented to the left visual field first and to the right visual field second produced more errors in matching judgements than the reverse order of presentation. These results with Japanese verbal materials accord with the finding from studies using verbal materials of Roman orthography.

Recently both Sasanuma, Itoh, Mori, and Kabayashi (1977) and Hatta (1977a, b) reported the results of tachistoscopic recognition experiments on *Kanji* materials presented in rapid succession. Sasanuma, et al. (1977) exposed tachistoscopically non-sense *Hirakana* and *Kanji* words in the right and left visual fields of normal right-handed subjects and found a significant right visual field superiority in non-sense *Hirakana* recognition and a non-significant trend towards the left visual fields superiority in randomly paired *Kanji* recognition. In Hatta's preliminary study

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(1977a), individual *Kanji* were tachistoscopically presented to the right or left visual field and he found a highly significant left visual field superiority.

These results strongly suggest that *Kana* and *Kanji* processing call for different types of cognitive functions in the cerebral hemispheres. This suggestion is also raised in recent studies with Japanese aphasic patients. Sasanuma (1975) reported that the abilities of some Japanese aphasics to use *Kana* signs and *Kanji* characters can be selectively impaired and that their recovery processes also vary with aphasic types. Yamadori (1975) also found a case of alexia with agraphia in a Japanese patient who can read words composed of logograms (*Kanji*), but who cannot read words composed of phonograms (*Kana*). These results suggest the possibility that different types of symbols are differentially processed by the two halves of the brain.

Thus the purpose of the first experiment in this study was to demonstrate lateral differences in performance level when *Kana* and *Kanji* were tachistoscopically exposed to the right and left visual fields of normal subjects.

In this experiment (unlike that of Sasanuma, et al. (1977) who used non-sense *Kanji*), single *Kanji* and *Hirakana* were used as stimuli in each trial because the intrinsic nature of *Kanji* (non-phonetic logograph) might be reduced in the case of random pairing and in ordinary Japanese orthography. *Katakana* are used only in the case of transcription of adopted words.

EXPERIMENT I

Method

Subjects. The subjects were 15 male and 15 female students, ranging from 19 to 23 years old, at the Osaka University of Education. All subjects filled in the Hatta and Nakatsuka Handedness inventory (Hatta & Nakatsuka, 1975) before the experiment. They were all

right-handed on the basis of this inventory. All subjects had normal or corrected-to-normal vision.

Apparatus and stimulus materials. A three-channel projector tachistoscope which consisted of Kodak Ektagraphic projectors and Gerbrand G-1165 shutters were used.

For *Kanji* task, a set of 40 single *Kanji* were selected from Kitao's *Kanji* List (Kitao, Hatta, Ishida, Babazono, & Kondo, 1977) for their high familiarity, concreteness and hieroglyphicity. These *Kanji* were taken from the 881 *Kanji* list for the standard use of primary school children by the Ministry of Education. Individual *Kanji* were presented in both visual fields. All *Kanji* were drawn in the Min-era type of print.

For the *Hirakana* task, a set of 40 *Hirakana* pairs were used. The *Kun-Yomi* or *On-Yomi* transcription of *Kanji* stimuli were used as *Hirakana* stimuli. In Japanese there are two possible acoustic renderings of *Kanji*. The *On-Yomi* or Sino-Japanese rendering derives from the Chinese pronunciation of the characters at the time of their first being used in Japan. The *Kun-Yomi* rendering is a native Japanese one. The rendering employed in the present study was selected by referring to the frequency of usage of each *Kanji*. Then among 40 *Hirakana* stimulus sets, six stimuli consisted of one *Hirakana* letter, 27 of two letters and seven of three letters. *Hirakana* letters were vertically arranged and printed in black Letraset No. JPN 1512. Arabic numerals from two to nine were also used as stimuli in order to assure adequate control for eye fixation.

Each stimulus of *Kanji*, *Hirakana* and numeral was pasted upon white paper, and a slide made of each one. The stimuli were back-projected onto a translucent screen 100 cm in front of the subject at eye level. The *Kanji* stimuli appeared in black 4.01° of visual angle right or left from the center of the screen, subtending a visual angle 1.49° . The *Hirakana* stimuli (one, two and three letters) appeared 4.01° to the right or left of the fixation, subtending (respectively) a vertical angle of 0.97° , 2.58° , and 3.44° . The fixation digit subtended a visual angle of 0.57° . The whole visual field

subtended a visual angle of 16.62° vertically and of 24.06° horizontally. The luminance of the screen was 49.32 mL (156.97 cd/m). Figure 1 shows an example of *Kanji* and *Hirakana* used in the experiment.

Procedure. Each subject attended two sessions: One for the *Kanji* task and one for the *Hirakana* task. These were on different days separated by two to five days. The order of the two tasks was counterbalanced across the subjects. Each session consisted of a practice session of 20 trials, followed by the test session.

The subject sat at a table, and his head was located on a chin-rest in front of the screen. For each trial, the subject was first asked to fixate on a small circle (0.83° of visual angle), presented as a preparatory signal exposed for 2 sec in the center of the lighted screen. Then one *Kanji* and one numeral were simultaneously displayed for 20 msec. The exposure duration of *Hirakana* was also 20 msec. During the intertrial interval of 20 sec, the screen was filled by a blank white slide. Two seconds before each exposure of the fixation circle, the experimenter said "focus" as a preparatory instruction. In advance of a practice session five trials with a slide having only a numeral as the fixation point were given to subjects accustomed to the procedure. The task of the subject firstly was to report which number appeared at the focus point and then which

TABLE 1
Mean percent correct recognition in the right and left visual fields for the *Kanji* and *Hirakana* tasks

Task	Right visual field	Left visual field
<i>Kanji</i>	69.7% (SD=10.6)	81.5% (SD=8.6)
<i>Hirakana</i>	69.4% (SD=8.5)	60.1% (SD=9.3)

Kanji or *Hirakana* was presented either on the left or the right side of the screen. Subjects were never informed of whether their responses were correct. In both test sessions for *Kanji* and *Hirakana*, 80 stimuli were presented to each subject allowing a total of 40 possible responses in each visual field. The order of presentation to each visual field was randomized. Scores for each subject were the number of correct letter identification in each visual field. Responses without correct identification of numbers at the fixation point were omitted from analysis.

Results

The mean percentage of correct recognition in the right and left visual fields for *Kanji* and *Hirakana* tasks are shown in Table 1. Examination of Table 1 indicates that the performance of the subjects

KANJI	会	心	馬	湯	指
	(meet)	(heart)	(horse)	(hot water)	(finger)
HIRAKANA	あ う	こ ころ	う ま	ゆ	ゆ び
KANJI WORD	都 会	安 心	馬 車	熱 湯	指 示
	(city)	(relief)	(coach)	(boiling water)	(indication)
MIXED WORD	と 会	あ ん 心	馬 し ゃ	ね っ 湯	指 じ

FIG. 1. Some samples of the stimulus materials used in the Experiment I and II.

on the *Kanji* task showed a significant left visual field superiority ($t=6.77$, $df=29$, $p<.001$), whereas a significant right visual field superiority on the *Hirakana* task is shown ($t=8.21$, $df=29$, $p<.001$). On the *Kanji* task, out of 30 subjects, 26 obtained higher scores for the left visual field, while only two obtained higher scores for the right visual field (two obtained nearly equal scores for both fields). On the other hand, out of 30 subjects, 28 obtained higher scores for the right visual field while only one obtained higher scores for the left visual field on the *Hirakana* task (one obtained equal scores for both fields). There was no significant sex difference for lateral differences in either task.

The literature previously describing a left visual field superiority for *Kanji* recognition was confirmed. However, when *Kanji* had been transcribed in *Hirakana* letters, the subjects recognized them more accurately in the right visual field. A significant right visual field superiority for the recognition of *Hirakana* letters is consistent with the results of the studies which employed alphabetical letters as verbal stimulus materials (Bryden & Rainey, 1963; Bryden, 1965; Kimura, 1966; Fontenot & Benton, 1972) as well as the studies in Japanese with one-*Hirakana* letter (Hatta, 1976), two-*Hirakana* letters (Sasanuma, et al., 1977), two-*Katakana* letters (Hirata & Osaka, 1967).

All of these results can be interpreted as confirming a cerebral dominance of the left hemisphere for processing verbal materials.

A significant left visual field superiority for single *Kanji* recognition is consistent with the results of the previous studies by Hatta (1977a, b) and Sasanuma (1977). Hatta (1977a) reported that when high familiarity and low familiarity single *Kanji* was presented tachistoscopically to the right or the left visual field, the subjects recognized more items correctly in the left visual field irrespective of their familiarity. A similar experiment (Hatta,

1977b) also reported left visual field superiority for the recognition of both abstract and concrete single *Kanji*. Recently, Sasanuma, et al., (1977) showed a trend towards left visual field superiority for recognition of randomly paired *Kanji*, although the difference was not significant.

These findings of lateralization in the opposite direction between *Kanji* and *Hirakana* suggest that the hemisphere processing involved in *Kanji* recognition is different from that for the recognition of *Hirakana* and *Katakana*.

Studies of Japanese aphasic patients seem to support this hypothesis. Yamadori (1975) reported a case of alexia with agraphia. The patient when presented with a daily newspaper could not read *Hirakana* and *Katakana* letters but reading ability of *Kanji* was preserved. The patient would read the *Kanji* part but disregarded the remainder of the sentence. Sasanuma (1975) also reported a longitudinal study of a number of aphasic patients who exhibited selective impairment for *Hirakana* and *Katakana* letters whilst the ability to process *Kanji* was well preserved. Other patients showed selective impairment of *Kanji* with remarkable preservation of *Hirakana* and *Katakana*. The recovery processes are also different depending upon the type of aphasia.

Studies with normal subjects therefore and the studies with aphasic patients suggest that recognition of *Kanji* and the other materials in Japanese orthography represent distinctively different models which themselves call for different types of cognitive function in the two hemispheres.

Based on these data one may speculate on the nature of the cognitive processes involved in *Kanji* recognition. As shown in Fig. 1, *Kanji* possesses more highly organized and distinctive graphic patterns rather than *Hirakana* and *Katakana*. This feature makes it a good candidate for direct visual mapping or for a wholistic type of processing (Cohen, 1973; Patterson &

Bradshaw, 1975). The *Kanji* in this experiment were of high hieroglyphic value as rated by Kitao, et al., (1977), and most of these *Kanji* were derived initially from the shape of concrete objects and have subsequently evolved to the present form. In school, children begin by learning *Kanji*, and most Japanese know them well. The *Kanji* used may easily correspond to concrete shapes and objects, and in this case a single *Kanji* in the left visual field should be recognized more accurately than that in the right visual field. On the other hand, the graphic representation of each *Kanji* is associated with both an inherent meaning and a phonological representation. Eventually, some kind of phonological activity may accompany the processing of *Kanji*. Thus, one may expect that the processing of *Kanji* can differ depending upon the degree of contribution of either the visual or phonological component.

EXPERIMENT II

As mentioned in Experiment I, *Kanji* characters have both visual and phonological aspects. Thus, it would be expected that either aspect of *Kanji* may be exploited to different degrees depending upon the specific type of processing required in a given situation. In other words, it would be expected that in the recognition of *Kanji* in which more of a phonological strategy than a visual strategy is called for, a right visual field superiority would be found; furthermore, on the task in which more of a visual strategy is demanded than a phonological strategy, a left visual field superiority would be extracted. To test this expectation, *Kanji* compound words (*Kanji* words) consisting of two letters and compound words of *Kanji* mixed with *Hirakana* (Mixed words) were employed in this experiment.

Kanji words were regarded as stimulus materials which depend more upon the

visual type of strategy than the phonological type of strategy in processing. This view is held because the visual aspect of each *Kanji* are seen as combining to give the word which the *Kanji* make up. On the other hand, Mixed words were presumed to be stimulus materials dependent on a phonological strategy rather than a visual strategy. This view is held because the phonological aspect which single *Kanji* inherently possesses is likely to be assimilated to the necessarily phonological material that the *Hirakana* stimuli present.

Method

Subjects. Thirty right-handed students (15 male and 15 female) participated in the experiment. They all met the criteria adopted in the first experiment.

Apparatus and stimuli. The apparatus used was identical with that in Experiment I.

For the *Kanji* task, a set of 40 *Kanji*-words pairs were used. The *Kanji* words were used in both visual fields. The *Kanji* words consisted of two-character *Kanji* words, one of the two-character *Kanji* was identical with those *Kanji* used in the previous experiment. The two-character *Kanji* word was arranged vertically. The *Kanji* used in Experiment I occupied an upper part of two-character words for the half of the stimuli and occupied a lower part for the remainder of the stimuli. These two-character *Kanji* words were all highly familiar ones which are commonly used in a primary school reading text.

Each of the *Kanji* pairs and arabic numerals from tow to nine were combined and used as the stimuli. These were rear-projected onto a translucent screen as described in Experiment I. The *Kanji* stimuli appeared in black 4.01° right or left from the center of the screen, which subtended a visual angle of 2.97° vertically and 0.97° horizontally. In the Mixed words task, a set of 40 stimuli which consisted of a single *Kanji* and *Hirakana* letters were used. They were all vertically arranged. The *Kanji* used were identical with those in Experiment I. The *Hirakana* letters were those which correspond to the *Kanji* added as *Kanji* words stimuli

in this experiment. The *Kanji* which were identical with those in Experiment I appeared in the upper part of the stimuli on half of the trials and appeared in the lower part of the stimuli on the other half of the trials. *Hirakana* as a part of these Mixed words stimuli consisted of one, two or three letters. The Mixed words and numeral were paired and made into slides. The Mixed word stimuli appeared in black on a translucent screen 4.01° off to the right or left from the center of the screen. They subtended a vertical visual angle of 0.97° (one *Hirakana* letter), 2.58° (two *Hirakana* letters), and 3.44° (three *Hirakana* letters) and a horizontal visual angle of 0.97°. The fixation digit subtended a visual angle of 0.57°. The visual angle of the whole visual field and luminance of the screen were identical with Experiment I. All *Kanji* characters were drawn in Min-era print. Fig. 1 shows an example of *Kanji* words and Mixed words in the present experiment.

Procedure. The general procedures were identical with those of Experiment I except that the stimulus exposure duration was 25 msec.

Each subject was given two separate sessions of the task for *Kanji* words and Mixed words on different days. The order of the two tasks was counterbalanced across the subjects. In each session, the subjects attended a practice session of 20 trials followed by test sessions. The task of the subjects was to report the central digit exposed at the center of the screen firstly and to report what *Kanji* words or Mixed words appeared either on the left or the right visual field. In each session, the total of 80 stimuli were presented to each subject allowing a total of 40 possible responses in each visual field. Scores for each subject were the number of correct whole-word identifications. Responses where correct report of the central digit was absent were omitted from analysis. This occurred on less than 2.5% of all trials.

Results

The mean percentage of correct identification in the right and left visual fields for *Kanji* words and Mixed words are presented in Table 2. It is shown that the

TABLE 2
Mean percent correct recognition in the right and left visual fields for the *Kanji* word and Mixed word tasks

Task	Right visual field	Left visual field
<i>Kanji</i> word	64.23% (<i>SD</i> = 16.29)	57.82% (<i>SD</i> = 16.18)
Mixed word	67.06% (<i>SD</i> = 16.14)	56.97% (<i>SD</i> = 16.71)

performance of the subjects both on the *Kanji* words and on the Mixed words showed a significant right visual field superiority ($t=3.46$, $t=4.27$, $df=29$, $p<0.01$). On *Kanji* words, out of 30 subjects, 22 obtained higher scores for the right visual field, while seven obtained higher scores for the left visual field (one showed equal scores for both visual fields). And on the Mixed words task, out of 30 subjects, only one showed higher scores for the left visual field, while 28 subjects obtained higher scores for the right visual field, and one subject showed equal scores for both visual fields.

Discussion

For both, *Kanji* words and Mixed words, a right visual field superiority was found. The direction of this laterality difference is not identical with the *Kanji* recognition task, but with the *Hirakana* letter recognition task of the previous experiment.

The hypothesis was as follows:

1. In *Kanji* words recognition, the subjects would show a superior recognition in the left visual field, because visual type of strategy or processing is called for as in the single *Kanji* recognition task.

2. On the other hand, in the Mixed words recognition task, it would be expected that a right visual field superiority exists because the phonological type of processing strategy is called for than visual type of processing strategy as in the *Hirakana* letters recognition.

As shown in Table 2, the second hy-

pothesis was supported, but the results of the present experiment were opposed to the first hypothesis. In the Mixed words task, the stimulus materials consisted of a single *Kanji* and *Hirakana* letters. In *Hirakana* letter recognition, several studies have already demonstrated a right visual field superiority (Hatta, 1976; Sasanuma, et al., 1977) while a left visual field superiority for single *Kanji* recognition was demonstrated in Experiment I and in the previous studies (Hatta 1977a, b). It appears that these results imply that *Kanji* recognition requires a specialized process of the left hemisphere in Japanese subjects. The Mixed words task might be regarded as presenting competing cues for phonological or for visual processing. From this point of view, the present results indicate what happens when there is competition between two different types of processing. That is with *Hirakana* processing (phonological) which favours the left hemisphere overwhelms *Kanji* processing (visual) which favours the right hemisphere. The stimulus materials of the present experiment consisted of mixed characters; the *Hirakana* letters component occupied much of the whole stimulus. This may be a further reason for a left hemisphere superiority.

For recognition of *Kanji* words, a left visual field superiority was expected following the hypothesis mentioned previously. The left visual field superiority for the recognition of a single *Kanji*, found in the first experiment, may be strengthened when two *Kanji* are used as stimuli. Thus an exaggerated left visual field superiority was anticipated. Nevertheless, the present results showed a right visual field superiority. Because of the combining of two *Kanji* characters, the trait which a single *Kanji* inherently possesses in favour of the right hemisphere (visual) processing, is apparently reduced. Instead, the left hemisphere function again becomes dominant as if the phonological aspects of *Kanji* become emphasized. It must be

borne in mind that with the *Kanji* words, which added another *Kanji* to the original *Kanji* used in Experiment I, the individual and multiple readings of single *Kanji* are reduced to a single acoustic rendering. Because of this reduction, the phonological processing might become an optimal strategy and so left hemisphere dominance is again found. In other words, in single *Kanji* recognition, when multiple reading of *Kanji* are possible, visual processing rather than phonological is employed. On the other hand when only a single rendering of the combined *Kanji* is available, phonological rather than visual processing is adopted. According to this hypothesis, it follows that the single *Kanji* task is achieved visually and *Kanji* words and Mixed words tasks phonologically.

Further, the case of the task randomly paired *Kanji* of Sasanuma, et al. (1977) might now be regarded as an intermediate situation. In their task, subjects would have more scope to search for some suitable strategy of their own in recognizing the stimuli. For some subjects then phonological processing might be employed and for some other subjects who processed the items of a non-coherent *Kanji* pair separately, visual proceedings might be favoured. That is, the non-sense configuration of the *Kanji* pairs of Sasanuma, et al. would not uniformly lead to phonologically based processing.

These results indicated as mentioned earlier, that *Kanji* have two different types of components, visual and phonological, and which component is exploited is due to the specific type of processing required in a particular task. And the visual component which is dominant in the case of single *Kanji* is cancelled or overwhelmed by the other type of component when some other letters, even of *Kanji* are added.

GENERAL DISCUSSION

Two experiments on perceptual asymmetry for Japanese *Kanji* recognition were

conducted. These experiments suggest that the direction of laterality differences of *Kanji* was dependent upon the types of processing required in a given situation. That is to say, in a single *Kanji* recognition task, *Kanji* were recognized more accurately from the left visual field (see Table 1) but once some other verbal materials of the same kind were added to single *Kanji*, *Kanji* were recognized more accurately from the right visual field (see Table 2).

These results indicate that the *Kanji* have properties which are essentially different from other types of verbal materials, such as *Hirakana* and *Katakana* in Japanese orthography and the *Alphabet* in Roman orthography.

Recently, Hokkyo (1976) proposed a hypothesis that in Japanese people phonetic symbols (*Hirakana* and *Katakana*) are recognized in the left hemisphere and logographic symbols (*Kanji*) are recognized in the right hemisphere. It appears that the present results on different kinds of *Kanji* recognition tasks do not support this hypothesis except in the case of a single *Kanji* recognition task. The present results rather suggest that *Kanji* recognition in Japanese are more fluid and less rigid than suggested by Hokkyo (1976).

As mentioned earlier, *Kanji* possesses a "visual" component. *Kanji* are logographic symbols which represent lexical morphemes. But this essential attribute of *Kanji* is coupled with highly organized and definite graphic quality. Some types of *Kanji* were derived from the shapes of concrete objects, and they have been modified into the present forms as shown in Fig. 2. This attribute of *Kanji* may be strongly reflected in single *Kanji* recognition, and thus a left visual field superiority is produced similar to the case of non-verbal materials (Kimura, 1966, 1969).

Whilst *Kanji* is associated not only with meaning but also with one or several phonological representations, some kind of phonological activities may positively accompany the *Kanji* processing. Thus, when some other phonological component of each *Kanji* (inherent to each *Kanji*), could be extracted this would be conducive to a right visual field superiority. The result of the second experiment in this study and the results of a random paired *Kanji* recognition task in Sasanuma's study, seem to confirm this interpretation.

At any rate, the present results strongly indicate that *Kanji* are quite unique symbols compared with alphabetical symbols, and Japanese people need the integrated

FIG. 2. The modification processes of Japanese *Kanji*.

action of both hemisphere processing systems in reading their texts; to a far greater extent that would the Westerner in reading his language.

Recently, Tsunoda (1975, 1977) suggested cross-cultural differences concerning a hemisphere dominance of auditory recognition. Tsunoda reported that animal sounds such as the song of a bird, a dog barking, mewling, croaking and chirping of a cricket were recognized dominantly in the left hemisphere in Japanese people, while for the Westerner, these sounds were recognized dominantly in the right hemisphere as well as other noises. This suggestion in addition to the present results on the recognition of *Kanji* strongly suggest that the verbal vs. non-verbal distinction in lateral differences in recognition may be less important in Japanese people.

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