Visual field differences in a deeper semantic processing task with Kanji stimuli

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A possible relation between semantic level of processing of Kanji stimulus and cerebral laterality effect was examined by using reaction time measure. Subjects were requested to classify the tachistoscopically and laterally presented single Kanji character into one of three categories and to press the appropriate button assigned to each category. The effect of concreteness of Kanji on this classification task was also examined. The results of RTs showed a right visual field superiority irrespective of response hand and Kanji concreteness. These results strongly suggest the possibility that a deeper semantic processing is carried out dominantly in the left hemisphere.

Key words: hemispheric differences, visual field differences, semantic level processing, Kanji, concreteness.

Recent studies with respect to hemispheric asymmetry have dealt with the possible effect of different stimulus processing modes. For example, Geffen, Bradshaw, and Nettleton (1972) asked subjects to match a pair of letters based on a physical code or acoustic code, and using the RT measure they showed that physical identity matching (AA) yielded a left visual field superiority and name identity matching (Aa) produced the reverse tendency. Within a similar framework, Bryden and Allard (1976) reported that the direction of visual field superiority and the degree of lateral differences vary with the visual complexity of the letters. Namely, a left visual field superiority was found with a script-like type face whereas a right visual field was superior for a print-like type face letter. These studies suggest that the right hemisphere is superior in physical processing while the left hemisphere is superior for phonological processing.

The above-mentioned studies implied that visual field differences were not determined by the kind of stimulus material (verbal vs. non-verbal) but by the relative importance of the processing types for the execution of the task. This process-oriented explanation can be viewed as an introduction of the idea of modern cognitive psychology into the study of laterality. The present study also on a similar line of thought. Craik and Lockhart (1972) suggested that the degree of information retention is dependent on the depth (type) of processing. According to them, as the analysis of a stimulus proceeds from acoustic or pictorial processing to a semantic one, the processing level grows deeper and retention is greatly improved.

Based upon the notion of Craik and Lockhart (1972), it could be considered...
that almost all previous laterality studies have dealt with the surface level of processing, and not deeper levels of processing.

The present study, then, intends to examine the relationship between deeper (semantic) processing and cerebral laterality effect by the use of Kanji characters as stimuli. To date, there have been two types of studies concerning this problem. One type of study used a lexical decision paradigm. Leiber (1976) presented words (meaningful, pronounceable), pseudowords (meaningless, pronounceable) and scrambled letter strings (meaningless, unpronounceable) to the left or the right visual field and asked subjects to decide whether each presented stimulus was a word or not. She found significant right visual field advantages for words, but for nonwords, regardless of their pronounceability. This result is interpreted as suggesting that meaningfulness rather than pronounceability is an important determinant of the cerebral laterality in a lexical decision task.

Day (1977) noticed another attribute of the word stimulus. Using various word classes; verbs, concrete nouns, abstract nouns, Day required his subjects to judge whether a vertically presented word was a noun or not, and measured the corresponding RTs for this task. The results showed no visual field superiority for concrete nouns whereas abstract nouns were recognized faster in right visual field. However, Shanon (1979), using an identical procedure and identical conditions to Day’s experiment (1977), could not replicate Day’s results. In fact, Shanon found no visual field difference for both concrete and abstract nouns. Though the materials used in these two studies were all meaningful words, the results were not consistent with Leiber’s.

The study of Bradshow, Hicks, and Rose (1979) is of interest in this respect. They showed that even when subjects were unable to identify the word at very briefly exposure duration, their lexical decision scores were significantly above chance level, and were better in the left visual field. One possible interpretation of this result is that the lexical decision task can be mediated by a shallower level of information processing that may be sensitive to orthographic regularity. Therefore this lexical decision paradigm is not adequate to research semantic level of processing.

Another type of study used a categorical classification task. Day (1977) required subjects to decide if the word presented at the left or right visual field was a positive instance or a negative one with respect to the superordinate category presented precedingly at the center of the visual field. The result showed a right visual field advantage for abstract nouns but no visual field difference for concrete nouns. Hatta (1977) also investigated the visual field differences for a similar categorization task and showed a superiority of right visual field for both letter and line-drawing stimuli. In view of these findings, the cerebral laterality effect in semantic processing seems to be equivocal and should be interpreted with caution until more data are accumulated.

The present study was designed to assess this issue by using a semantic categorization task with Kanji stimuli. In this study, concreteness was manipulated because it was thought that it might be an important feature of the semantic content of linguistic stimuli. Though several investigators have examined the effect of concreteness of stimuli on cerebral laterality effect (Ellis & Shepherd, 1974; Hines, 1976, 1977; McFarland, McFarland, Bain, & Ashton, 1978; Orenstein & Meighan, 1976), the results are not consistent. If concreteness is closely related to mental imagery, which is assumed to have visuo-spatial nature, the recognition of concrete Kanji stimuli is expected to show a different cerebral laterality effect from abstract Kanji stimuli.
Method

Subjects. A total of 36 experimentally native people served as subjects; eleven were male and twenty five were female. All subjects were undergraduates or graduates of Osaka University of Education and were strongly right-handed, this being assessed using the H. N. Handedness Inventory (Hatta & Nakatsuka, 1975). All the subjects had normal vision without the use of corrective lenses.

Apparatus. The stimuli were presented by a three-channel projector tachistoscope, which consisted of three Kodak Ektagraphic projectors with electric shutters (Ralph Gerbrands, Model G-1169), positioned 90 cm behind the rear-projection screen. The projection field subtended 24° of visual angle horizontally and 16.2° of visual angle vertically. Each Kanji stimulus was presented at angle of 6.3° from center of screen and it subtended 3.2° of visual angle horizontally and 1.5° of visual angle vertically. Exposure duration of the slides and inter-stimulus intervals were controlled by the multi-time unit (Sanwa Co.). The digital-timer started at the onset of each stimulus and was stopped by the pressing one of three buttons installed on a response board placed in front of the subject. These response buttons were arranged to fit the positions of the subject's index, middle and ring fingers.

Stimuli. The stimuli were 36 Kanji characters drawn in Mingera type of print. They were all high-familiar characters with a mean familiarity value of 4.11, which was computed from Kitao's Kanji List (Kitao, Hatta, Ishida, Babazono, & Kondo, 1977), and the number of strokes per character being 3 to 15. These stimuli

<table>
<thead>
<tr>
<th>Category name</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals</td>
<td>豚 蚕 象 (pig) (silkworm) (elephant)</td>
</tr>
<tr>
<td>Plants</td>
<td>稻 麦 竹 (rice) (wheat) (bamboo)</td>
</tr>
<tr>
<td>Body parts</td>
<td>鼻 足 腕 (nose) (foot) (hand)</td>
</tr>
<tr>
<td>Numerals</td>
<td>壹 千 亿 (1) (a thousand) (10 billion)</td>
</tr>
<tr>
<td>Emotions</td>
<td>怒 喜 楽 (anger) (joy) (pleasure)</td>
</tr>
<tr>
<td>Warmth</td>
<td>寒 暑 暖 (cold) (hot) (warm)</td>
</tr>
</tbody>
</table>

Table 1 Examples of stimulus materials used in the Experiment
consisted of six categories, half of the categories being highly concrete, i.e., animal, plant and body parts, and the remaining half being highly abstract, i.e., numeral, emotion and warmth. Each of these six categories consisted of three instances. Examples of these stimuli are shown in Table 1. In addition to these Kanji stimuli, single digits, 0 from 9, were used in order to confirm the subject’s central fixation.

Procedure. The experiment consisted of two sessions of 36 trials each. In one session, 18 concrete Kanji characters were used as stimuli and in another session 18 abstract Kanji characters were used. All subjects performed both sessions, the order of the two sessions being counterbalanced across subjects. Every item of each category was presented once in both the right and the left visual fields, so that subjects performed 36 trials in all in each session. The order of stimulus presentation with respect to visual field was also randomized.

The subject sat at a table facing a translucent screen with his/her head located on a chin-rest to hold the viewing distance constant. Each subject was informed that he/she would see a series of slides displayed on the screen and that each of these slides would contain a small cross at the center of the screen. The subject was instructed to keep his/her central fixation on the small cross at the center of the screen. Two seconds later, Kanji character was presented for 150 ms to either the left or right of the central fixation digit. The task of the subject was to decide to which of the three superordinate categories the stimulus belonged, and to press the appropriate button as swiftly and accurately as possible. The manual response board consisted of manually operated response buttons for each four fingers except for little finger. In this experiment, the three buttons for the index, middle and ring fingers were used. They were assigned to each of the three categories. The combination of categories and response fingers was determined by a 3 × 3 Latin Square with each row determining 12 subjects. One half of the subjects responded with their right hand and other half with their left hand. Immediately after the response, the subject was asked to report the central digit verbally to confirm central fixation.

The practice trials were continued until improvement levelled off at a mean RT of less than 1 000 ms for 10 trials. The intertrial interval was 7 s. The test trials followed after these practice trials.

Results

There were 4.2% errors to stimuli presented in the left visual field, and 2.9% to those presented in the right visual field. There was no effect of visual field of presentation on error rates. As error rates were negligibly small and did not distribute differentially, they were excluded from the following analysis.

Mean reaction times (RTs) of correct responses were calculated for each individual subject as a function of concreteness, visual field and response hand. In order to reduce variability in the RT distribution, the data exceeding 1 500 ms were discarded and not replaced. The percentage of the trials on which subjects could not report the central fixation digit was less than 1.7% of all trials and these data were omitted. Table 2 presents the mean RTs and standard deviations.

A three-way analysis of variance, visual field (right vs. left) × concreteness (concrete vs. abstract) × response hand (right vs. left), was carried out. The first two variables were within-subjects factors and the residual variable was a between-subjects factor.

The result of the analysis showed a significant main effect of visual field; RTs in the right visual field were faster than those of the left visual field \[ F(1, 34)=31.06; \ p<0.01 \]. Overall RTs appear to favor the right response hand, but the effect of
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Table 2
Mean reaction times (in ms) for Kanji with two concreteness levels, presented in left or right visual field (LVF, RVF) and responded with left or right hand (LH, RH)

<table>
<thead>
<tr>
<th>Concreteness</th>
<th>LH LVF</th>
<th>LH RVF</th>
<th>RH LVF</th>
<th>RH RVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>854.2</td>
<td>821.1</td>
<td>836.9</td>
<td>795.2</td>
</tr>
<tr>
<td>Abstract</td>
<td>866.4</td>
<td>820.5</td>
<td>836.7</td>
<td>794.2</td>
</tr>
</tbody>
</table>

Numbers in parentheses refer to standard deviations.

response hand was not significant. Nor other significant main effect or interaction was recognized.

Discussion

The present study was designed to examine the relationship between semantic processing and the cerebral laterality effect by means of a categorical classification task. The stimuli were Kanji characters and their concreteness was also manipulated.

The result indicates a right visual field superiority regardless of response hand or Kanji concreteness. This result is interpreted as showing that the left hemisphere is superior in the execution of the Kanji categorization task.

This result is essentially consistent with the result of Hatta (1977, experiment 2), and partially consistent with the result of Day (1977, experiments 2 and 3) but is not consistent with Martin (1978).

Hatta (1977) reported right visual field superiority in his study, in which the words written in Kana characters were used as stimuli, and the subjects were asked to decide whether the category of comparison stimulus presented to the right or the left visual field was the same as the category of the standard stimulus or not. While the present study used Kanji characters as stimuli, the tendency of the result was identical to Hatta's study. Thus the present study indicates that even if the stimulus is described either in logographic symbols, known to be processed more favorably when presented to the left visual field (Hatta, 1977; Hayashi & Hatta, 1978; Sasanuma, Itoh, Mori, & Kobayashi, 1977) or in phonographic symbol, tasks which required categorical classification are carried out predominantly through left hemisphere processing.

Day (1977) required his subjects to judge whether a word which was vertically presented at the right or left visual field was a member of the superordinate category which was precedingly presented at the center of the visual field, and showed right visual field superiority for abstract words. Hatta (1977) demonstrated right visual field superiority using only concrete nouns as stimuli. From these findings it would seem reasonable to conclude that the semantic categorization is primarily performed in the left hemisphere regardless of stimulus concreteness.

Clinical literature supports this notion. Wilkins and Moscovitch (1978) reported that when patients with left temporal removals were asked to classify stimuli into either living or man-made objects, their performances were poor. But there was no impairment on the task of size comparison in which subjects were required to classify the objects as larger or smaller than a chair. This result suggested that perceptual features concerning physical attributes, e.g., size, may be assessed by the right hemisphere, whereas semantic cognition is executed in the left hemisphere.
The result of Martin (1978) is very puzzling in this context. She presented a list of words successively to the right or the left visual field and asked subjects to recall the relevant item belonging to the category of which the subject was informed before or after each block of trials. No visual field differences were obtained for the task. The discrepancy between Martin's result and the other studies can not be easily explained, but it is plausible to think that the members of the categories used in her study could also be distinguished by their physical forms because Martin used only two categories.

The present study showed the same direction of visual field superiority for both concrete and abstract Kanji stimuli. However some investigators refer to the possibility that there are some differences between the superiority of the cerebral processing for concrete and abstract words (Ellis & Shepherd, 1974; Day, 1977; Hines, 1977; Shanon, 1979). They assumed that concrete words can easily generate mental imagery whereas abstract words do not, and because of the visuo-spatial nature of imagery concrete words would produce right hemisphere (left visual field) superiority.

In the present study, however, different hemispheric asymmetry was not obtained between concrete and abstract Kanji. This might be interpreted as following: Word concreteness and imaginability are highly correlated, however they are not completely identical. Recently, Baddeley, Grant, Wight and Thomson (1975) reported that mental visualization (imagery) impaired the visual tracking task but impairment of word memory by the visual tracking task did not interact with word concreteness. The former result implies that mental imagery and visual tracking task share a common visual system, and the latter result implies that concreteness is not always directly related to visual activity. From their results, they inferred that the formation of images is a mental activity or a strategy applied to input information, and that it is related to the control process of short-term working memory, while concreteness is defined as a fundamental semantic feature of a word stimulus. That is to say, concreteness is linked to its representation in long-term semantic memory. This assumption suggests that semantic processing of concrete words in the present categorical classification task, which is based on longterm semantic memory, does not necessarily evoke mental imagery, therefore does not always yield left visual field superiority. This interpretation seems fairly valid but further research will be needed.

To revert, in conclusion, to the issue of the relation of the cerebral laterality effect with the levels of processing—although the present experiment was not specifically designed to compare the effect in shallower level of processing with that in deeper level of processing, the consideration of the results does suggest that semantic (deeper) level of processing, e.g. categorical classification in this study, might be carried out primarily in the left hemisphere irrespective of the stimulus concreteness.

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