

# Hemispheric Lateralization in Processing Emotional and Non-Emotional Kanji Words

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## Abstract

The purpose of this study was to investigate the contribution of both hemispheres to the processing of positive, negative, and non-emotional Kanji words in normal individuals. Right-handed subjects were asked to read aloud the Kanji word presented in the visual half-field. Results showed that responses to positive and non-emotional words were more accurate in RVF than those in LVF, but no difference was found for negative emotional words. Reaction time results indicated that processing of negative emotional words was faster in RVF than in LVF although there were no visual field differences for positive and non-emotional words. These findings were interpreted as suggesting that the right hemisphere has a processing system for emotionally negative Kanji words.

*Keywords:* hemispheric lateralization, emotional word, Kanji, visual field

The present study is designed to examine the contribution of the left and right hemispheres to the processing of positive, negative, and non-emotional Kanji words in normal subjects. Japanese may be written in any of three different orthographic systems (Kanji, Hiragana, and Katakana). Kanji are essentially non-phonetic logographic symbols while Kana (Hiragana and Katakana) are phonetic syllables. Kanji as an ideogram represents a certain unit of meaning. On the other hand, Kana as a phonogram represents a spoken syllable or 'mora', and the sound-to-script correspondence is strictly one-to-one (Sugishita, Otomo, Kabe, & Yunoki, 1992).

It has been shown that the right hemisphere plays a special role in processing the emotional properties of non-verbal stimuli (Nagae, 2010). For example, hemispheric specialization

studies indicated a left visual field superiority in discriminating emotional facial expression (Alvarez & Fuentes, 1994; Indersmitten & Gur, 2003; Strauss & Moscovitch, 1981), and a left ear superiority in discriminating emotional non-verbal vocalization (Mahoney & Sainsbury, 1987), or in processing affective prosody (Bryden & MacRae, 1989; Grimshaw, Kwasny, Covell, & Johnson, 2003). These studies support the *right hemisphere model* for processing of emotional properties of the stimuli, an advantage which possibly arises because of the greater involvement of the right hemisphere in mechanisms of automatic and behavioral arousal (Collins & Cooke, 2005; Graves, Landis, & Goodglass, 1981; Heller, 1993; Landis, 2006; Nagae & Moscovitch, 2002; Richards, French, & Dowd, 1995; Schmitt, Hartje, & Willmes, 1997).

Some studies, however, suggest that there is differential hemispheric specialization for emotion supporting the *valence model*. This model posits that the left hemisphere specializes in the processing of positively valenced emotions, whereas the right hemisphere specializes in the processing of negatively valenced emotions (Ali & Cimino, 1997; Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Borod, et al., 1998; Coney & Fitzgerald, 2000; Ueda et al., 2003; Van Strien & Morpurgo, 1992). Davidson (1992, 1998) indicates that the valence model may reflect a cerebral hemispheric difference in the neural representation of approach-avoidance behaviors.

Experimental and clinical research has investigated cerebral hemispheric differences in processing emotional properties of verbal stimuli. Neither the right hemisphere model nor the valence model has been supported consistently by results of the visual half-field studies on perception of emotional words. Graves, Landis, and Goodglass (1981) indicated that emotional words were processed more accurately than non-emotional words in the left but not the right visual field. It supports the right hemisphere model. However, in their study most of the emotional words were negative. The lack of sufficient numbers of positive and negative stimuli in the study of Graves et al. (1981) may not have permitted an adequate test of the right hemisphere and valence models.

Ali and Cimino (1997) investigated hemispheric lateralization of perception and memory for emotional verbal stimuli in normal subjects by presenting positive, negative, and non-emotional words and non-words in the left or the right visual field. Their findings supported the valence model, with left hemisphere mediation of explicit memory for positively valenced emotional words and right hemisphere involvement in explicit memory of negative words. Strauss (1983), however, found a right visual field superiority for both emotional and non-emotional words, contrary to both the right hemisphere or valence models. Eviatar and Zaidel (1991) also showed no evidence to support these two models. In their study, emotionality of words had the same effect in left and right visual fields.

Because alphabetic, phonologically-based scripts may bias processing of all words to the left hemisphere (Moscovitch, 1986), investigating emotional laterality may benefit from using logographic scripts such as Kanji. Using emotional and non-emotional Kanji words, Nagae (1998) found that non-emotional Kanji words were reported more accurately in the right visual field than in the left, but no visual field differences for emotional Kanji words. Nagae (1998) interpreted the findings as supporting the view that the right hemisphere processed emotional Kanji words just well as the left. However, the emotional Kanji words in Nagae's study included two kinds of words, positive and negative emotional words. Because this study did not control the emotional connotation of Kanji words as a within-subjects variable, it was not an adequate test to investigate the valence model.

The purpose of this study is to investigate the contribution of left and right hemispheres in processing of positive, negative, and non-emotional Kanji words in normal subjects. Because all stimuli in this study are verbal, it is predicted that once the data is collapsed across emotionality (Moscovitch, 1986), participants will demonstrate an overall right visual field advantage in the identification task. If the processing of emotional stimuli is mediated by the right hemisphere, as the right hemisphere hypothesis predicts, an advantage for both positive and negative emotional Kanji words is expected for words presented to the left visual field. An advantage for non-emotional Kanji words is expected for words presented to the right visual field.

If the valence hypothesis is correct and the processing of positive and negative emotional stimuli is mediated by the left and right hemisphere, respectively, then it is predicted that positive emotional Kanji words would favor the right visual field and negative emotional Kanji words would favor the left. Processing of non-emotional Kanji words would be better in the right visual field than in the left visual field. Furthermore, if there are no cerebral hemispheric differences in processing the emotional properties of Kanji words, positive,

negative and non-emotional Kanji words will be processed better in the right visual field than in the left visual field.

In addition, the present study examines sex difference in processing of emotional and non-emotional Kanji words. Cahill (2005), Gasbarri et al. (2007) and Wager, Phan, Liberzon, & Taylor (2003) show that the subject's sex is powerful determinant of hemispheric differences in processing emotion. In visual laterality studies, Graves et al. (1981) found a right hemisphere advantage in processing emotional words in males only, whereas Strauss (1983) did not find such a difference.

## Method

### *Participants and Design*

Participants were 20 right-handed males (mean age = 20.56 years) and 20 right-handed females (mean age = 20.74 years) at Fukuoka University of Education who participated for course credit. Annett's (1967) handedness questionnaire was used to assess the handedness of the participants. All had normal, or corrected to normal, visual acuity. Participants indicated they did not abuse alcohol or drugs. One between-subjects factor - sex (male, female) and two within-subjects factors - emotional connotation of words (positive, negative, and non-emotional) and visual field (left and right) - were used in a  $2 \times 3 \times 2$  factorial design.

### *Stimulus materials*

Twelve positive, 12 negative emotional Kanji and 12 non-emotional Kanji which were rated the emotional goodness (Horikawa & Nagae, 1997) were used. All Kanji were nouns and two-Kanji compound words (Table 1). Ming-style characters were used as Kanji stimuli. The emotional goodness of Kanji words was rated according to the procedure used by Rubin & Friendly (1986). Positive emotional Kanji consisted of words rated over 5.08 points in emotional goodness (mean=6.03, SD= .28) on a 7-point scale. Negative emotional Kanji consisted of words rated under 3.50 points in emotional goodness (mean=2.37, SD= .23). Non-emotional Kanji consisted of words rated between 3.59 and 4.98 points in emotional goodness (mean=4.22, SD= .17). The emotional goodness of the three word groups differed significantly from one another ( $F(2, 22) = 2410.78, p < .01$ ). A post-hoc tests (Ryan's method) indicated significant differences among three word groups ( $p < .01$ , respectively).

The number of strokes of Kanji character is a measure of the complexity of the character. The number of strokes of each word type was as follows; positive emotional Kanji (19.92, SD= 5.35), negative emotional Kanji (18.42, SD= 4.46), non-emotional Kanji (17.00, SD= 3.72). The group differences of the number of strokes of Kanji characters were not significant.

Table 1 Examples of positive, negative, and non-emotional Kanji words used in the experiment

Positive		Negative		Non-emotional	
愛情	affection (6.32)	陰気	gloominess (2.09)	期間	term (4.12)
快感	pleasure (5.69)	恐怖	fear (2.52)	経営	management (4.29)
感動	excitement (6.46)	苦痛	pain (2.43)	材料	material (4.17)
幸福	happiness (6.45)	激怒	rage (2.64)	周囲	surroundings (4.22)
陽気	cheerfulness (5.77)	絶望	despair (1.86)	設計	design (4.47)
愉快	enjoyment (5.91)	悲惨	misery (2.32)	入場	entrance (4.06)

*Note.* The emotional goodness is presented in parentheses.

### Apparatus and Procedure

All participants were individually tested using a tachistoscope, which was controlled by a microcomputer (Compaq-Deskpro) and a monitor (Sony Multiscan G400). Participants were tested with the same overhead lighting conditions in the room. All stimuli were presented in black on a white background. Each of Kanji words appeared at 3.5 degrees of the visual angle to the left and right from the point of fixation, and subtended an area 1.9 high by 1.0 degree wide. The verbal response triggered a voice-sensitive relay and latency from stimulus onset to voiced response was measured on each trial.

The participants were given a visual half-field presentation task. They were asked to fixate their gaze on a small cross for 2 sec in the center of the screen. Seventy-two Kanji words were presented in either the left or the right visual field in random order. Half of these trials were left-side, the other half, right. Each word was presented once to each visual field. All properties of Kanji words were balanced across visual fields. Kanji stimuli were presented for a duration of 70 msec. The task was to read a word aloud immediately after presentation. Before these trials, participants were presented with twelve practice trials. The Kanji words of the practice trials were different from those in the experimental conditions.

## Results

### Accuracy

The accuracy results are shown in Figure 1. Analysis of variance of correct identification indicated that the main effect of visual field was significant,  $F(1, 38)=7.25$ ,  $p < .05$ . Correct identification in the right visual field was better than that in the left visual field. The main effects of emotional connotation of words and sex were not significant.

The emotional connotation of words  $\times$  visual field interaction was significant,  $F(2, 76)=4.12$ ,  $p < .05$ . A post-hoc tests (Ryan's method) we performed to qualify this interaction indicated that identification of non-emotional words and positive emotional words was better for words

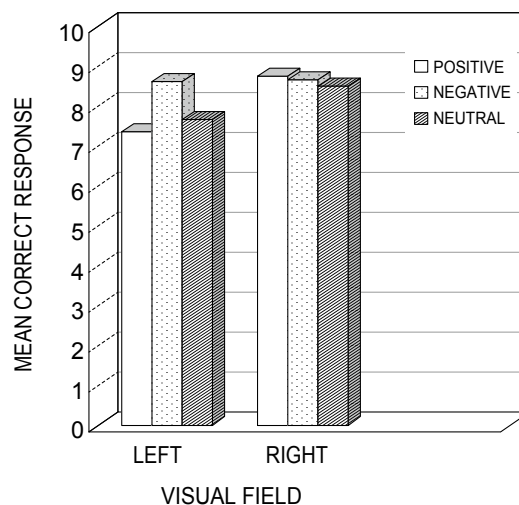


Figure 1 Mean correct responses as a function of emotionality of Kanji word and visual field.

presented in the right than in the left visual field (non-emotional words,  $p < .05$ ; positive emotional words,  $p < .01$ ), with no significant visual field differences for negative emotional words.

Further analyses showed that identification of negative emotional words in the left visual field was better than that of non-emotional and positive emotional words ( $p < .05$ , respectively), with no significant differences for three word conditions in the right visual field. The difference between non-emotional and positive emotional words was not significant. Other interactions were not significant.

### Reaction time

The results of reaction time of correct responses are shown in Figure 2. Analysis of variance indicated that the main effects of emotional connotation of word and visual field were significant,  $F(2, 76)=8.09$ ,  $p < .01$ ;  $F(1, 38)=6.94$ ,  $p < .05$ , respectively). Reaction time for positive and non-emotional words was shorter than that for negative emotional words. The main effect of sex was not significant.

The emotional connotation of words  $\times$  visual field interaction was also significant,  $F(2, 76)=4.66$ ,  $p < .05$ . This interaction showed that the reaction time for negative emotional words was shorter in the right visual field than in the

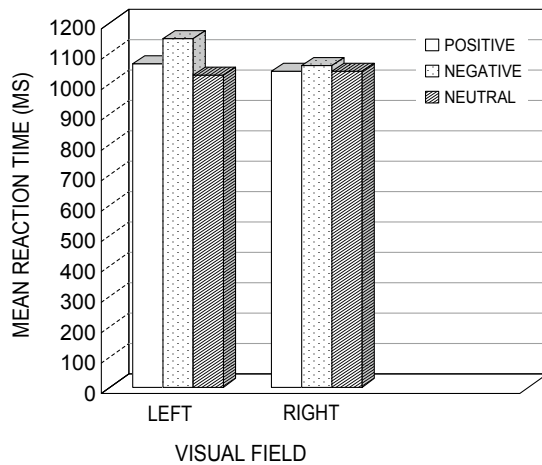


Figure 2 Mean reaction time (ms) as a function of emotionality of Kanji word and visual field.

left visual field ( $p < .01$ ), with no significant visual field differences for non-emotional and positive emotional words.

Further analyses indicated that the reaction time for non-emotional and positive emotional words was shorter than that for negative emotional word in the left visual field ( $p < .01$ , respectively), with no significant differences for three word conditions in the right visual field. The difference between non-emotional and positive emotional words was not significant. Other interactions were not significant.

### Discussion

The main results of this study were the observed effects of emotional connotation of words  $\times$  visual field interaction on accuracy and speed of identification. Figure 1 indicates that accuracy of identification was equivalent for positive, negative and non-emotional words in the right visual field but negative emotional words were identified more accurately than positive and non-emotional words in the left visual field. Figure 1 showed that positive, negative, and non-emotional words were identified equally quickly in the right visual field while negative emotional words were identified more slowly than positive and non-emotional words in the left visual field.

Results on accuracy were consistent with ones of past studies that examined the visual field effects on the processing of verbal stimuli (Nagae, 1992, 2012). Many experiments indicated that there was a left hemisphere advantage for verbal stimuli. However, the results of this study demand a partial revision of the idea that the left hemisphere favors the processing of all verbal materials. The present study indicated that the left hemisphere advantage for verbal processing applies to positive and non-emotional words but not to negative emotional words. No visual field advantage was found for processing of negative emotional words although the accuracy for negative emotional words was higher than that for positive and non-emotional words in the right hemisphere.

The results indicate that the negative meaning of words may be processed in the right hemisphere. They provide partial support of the valence model in that the left hemisphere is more involved in processing positive emotions while the right hemisphere is more involved in processing negative emotions. However, one aspect of the valence model was not supported, because the present study indicated that there were no significant differences across three word conditions in the left hemisphere. The right hemisphere has an ability to process a negative meaning in an emotional word at a high level although emotional words were processed in the left (verbal) hemisphere without the emotional value of words at a high level. These findings agree with those of Richards, French, and Dowd (1995) who found a right hemisphere advantage for negative emotional words.

Reaction time results indicated that word processing in the left hemisphere was faster than that in the right hemisphere. However, there was the interaction effect such that processing of negative emotional words was faster in the left hemisphere than in the right hemisphere although there were no visual field differences for positive and non-emotional words. Furthermore, while the verbal processing in the left hemisphere was not influenced by the emotional connotation of words, processing of negative emotional words in the right hemisphere was slower than that of

positive and non-emotional words.

It is thought that the right hemisphere had its own processing system for negative emotionality of words. This system in the right hemisphere processes the negative emotional meaning of the word. The result of right hemisphere indicates that there is a speed/accuracy tradeoff with negative emotional words; that is, higher accuracy is achieved through slower and more deliberate processing. As the systems needed to process positive and non-emotional words are not represented in the right hemisphere, these words are transferred to the left hemisphere to be processed. As a result, although it did not take as long to process the words, accuracy suffered. The reaction time data support the idea that the right hemisphere has an ability to process the negative emotional meaning of the words.

No sex differences were found in this experiment, consistent with Strauss' report (1983). Although there are a lot of studies suggesting sex differences, with females typically better, more accurate, and quicker in processing emotional stimuli than males, it is indicated that there is a tremendous variability in lateralization within a given sex (Springer & Deutsch, 1998). It is thought that this variability makes it very difficult to detect real, but small, differences between the sexes.

In conclusion, the results of this study indicate that although the emotional Kanji words are processed with general Kanji words in the same way by the left hemisphere, the right hemisphere processed the negative emotional Kanji words to the same extent as the left hemisphere. This conclusion would apply to any verbal/ emotional material.

Using positron emission tomography (PET), Sakurai and Momose (1994) found that reading Kanji words activates the posterior inferior temporal area (PIT) of both hemispheres, Broca's area on the left side. Iwata (1984) showed that the processing of Kanji and Kana scripts involves different intrahemispheric mechanisms. He proposed the hypothesis that Kanji word is processed in the nervous system circuit of visual area-PIT-Wernicke area. In addition, he thought that the right PIT may be related to

the processing of the meaning of Kanji word, especially its emotional connotation. Sakurai et al. (1992) showed that the left PIT processes highly complex morphological features of Kanji.

Our results are related to Kunst-Wilson and Zajonc's (1980) proposal that cognitive and evaluation processes act independently. They asked participants to judge which figure they liked or which figure they perceived when they were presented a pair of known and unknown figures. The results showed that the participant preferred known figures over unknown ones, even although the figure identification was at chance. This study showed that participants could judge the emotional meaning of the word correctly even if they do not know what the stimulus is, and demonstrates that the cognitive and the emotional evaluation processes are performed separately.

These findings, as well as our own, fit into a spreading-activation model of meaning and emotion proposed by Bower (1981). According to this model, it is thought that an emotional Kanji word has a semantic network, which is constituted by formal and emotional concepts. The formal concept indicates the meaning of a word. Bower (1981) posits that the semantic network has a node, which represents emotional tone. The present study indicated that the cerebral hemispheric advantage was influenced by the emotionality of Kanji word. This finding might be interpreted in light that there are formal and emotional nodes in the semantic network. Accordingly, it could be thought that the left hemisphere has the semantic network constituted by formal and emotional concepts but the right hemisphere has one constituted by only negative emotional-concepts. While the right hemisphere could process the negative emotional-words by its network, it could not do so for positive and non-emotional words.

The results on reaction time of this study support the above. Figure 2 showed that the reaction time for negative emotional words was longer than other two conditions in the left visual field. One interpretation of this finding is that the negative emotional-words projected to the right hemisphere are processed by the

semantic network associated with the negative emotional-nodes. On the other hand, the positive and non-emotional words projected to the right hemisphere are not processed by its semantic network, and are transferred immediately to the left hemisphere. It could be thought that this processing difference accounted for the difference in reaction time between negative emotional-words and other two conditions in the left visual field.

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