Hemispheric asymmetry as a function of word imageability in recognition memory task

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The word processing ability of the right hemisphere with regard to word imageability was examined by the running memory span procedure. Forty right-handed college students participated. Seventy-six stimulus pairs were successively projected onto the both sides of a fixation-point, and the subjects were asked to judge if one of the presented stimulus pair has been presented before as quickly and accurately as possible. Each pair consisted of a highly imageable noun and a less imageable noun. As mental imagery has a facilitating effect on memory but not perception of words, memory load was systematically manipulated. Right visual field superiority was found for both HI and LI nouns at the immediate recognition condition. However, no significant visual field differences were found for HI nouns at delayed recognition conditions. These results suggest that the right hemisphere may take a certain role in mental imagery for memory tasks.

Key words: visual laterality effect, right hemisphere function, word imageability, recognition memory, running memory span.

Since the studies of commissure-sectioned patients revealed that the right brain hemisphere possesses certain linguistic skills such as an ability to comprehend common object nouns and, to some extent, adjectives (Gazzaniga, 1970; Gazzaniga & Hillyard, 1971; Zaidel, 1976, 1978), some investigators have attempted to determine whether this clinical finding can be generalized to the right hemisphere of the intact normal population. Ellis and Shepherd (1974) examined this question using concrete and abstract words in a bilateral presentation method with normal subjects. They showed that there was no significant difference between the recall of concrete words and that of

abstract words when they fell in the right visual field (RVF), however words were recalled significantly more for concrete words than abstract words when the stimuli fell in the left visual field (LVF). These results were interpreted as showing that high imageability of concrete words facilitates their processing in the right hemisphere.

Hines (1976) replicated Ellis and Shepherd's experiment using similar word samples, and obtained a similar result. In another study Hines (1977) also examined the generality of this Ellis and Shepherd's effect with much larger stimulus sample, and confirmed once again the effect found by Ellis and Shepherd.

Although there are some contradictory findings concerning right hemisphere superiority in the recognition of concrete words, Bradshaw (1980) concluded in his review that the right hemisphere has a direct lexical access route for concrete or imageable words, presumably via directly generated mental imagery.

It should be noted that though word imageability and concreteness are closely correlated, this relationship is not always

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so rigorous, particularly for some abstract words. For example, words like ghost, phantom, anger, etc. are completely abstract but they have high imageability value (Paivio, 1971). In addition, there is a study showing that concreteness and imageability are separable independent factors, both of which enhance memory (Baddeley, Grant, Wight, & Thomson, 1975). Moreover, the idea that the word imageability rather than word concreteness may be the factor responsible for the visual word recognition of the right hemisphere is also suggested by some clinical studies (Mercel & Patterson, 1978; Richardson, 1975).

To date, however, there have been only a few available studies concerning the relationship between word imageability per se and right hemisphere linguistic capability in normal subjects, and the results of these studies are not congruent each other. Using a lexical decision task with a RT measure, Day (1979) showed a greater RVF superiority for low imageability (LI) words than for high imageability (HI) words, and no VF asymmetry for HI words. In contrast, in a similar lexical decision task employing vertically arranged Chinese character words, Tzeng, Hung, Cotton, and Wang (1979) could not find any VF asymmetry differences between HI and LI words: A greater RVF superiority was obtained for both word categories regardless of imageability. The present study was thus designed to reexamine the relationship between the right hemisphere visual word recognition ability and word imageability.

Since memory processes involving imagery functioning have been overlooked in the past studies, a running memory span (RMS) procedure was used in the present study. All of the previous studies used either an identification (word naming) task or a lexical decision task, however there are some evidences that the referential meaning of a word (imageability and

concreteness) does not facilitate its perceptual recognition threshold, word naming time and lexical decision time. But it facilitates memory performance (Paivio & O'Neill, 1970; Richardson, 1976).

It might be considered that the previous studies using identification or lexical decision task have not examined the effects of word attributes such as imageability and concreteness on the linguistic skills of the right hemisphere appropriately. In other words, less demands on memory processes in these of tasks may be responsible for inconclusive results concerning the effect of word imageability on the right hemisphere's word processing abilities. Then, the aim of the present study was to examine the effects of word imageability upon the linguistic skills of the right hemisphere more appropriately or precisely using a RMS procedure. Kelly and Orton's (1979) mixed-imageability presentation mode which simultaneously presents a less imageable word to one VF and a more imageable word to the other was used. This procedure was adopted to make it possible that the degree of difficulty of processing performed by each hemisphere can be manipulated. That is to say, because highly imageable word is easier to recall than less imageable word (Paivio, 1971, 1972), a condition in which a less imageable word to the RVF in a mixed imageability mode should offer a more difficult task to the left hemisphere than a task offered by a condition in which a highly imageable word to the RVF. If the hypothesis advanced by Moscovitch (1976) is true, which states any linguistic skills represented by the right hemisphere may be suppressed by the dominant linguistic function of the left hemisphere unless its influence can be weakened, one could expect that, because the influence of the left hemisphere over the right hemisphere should lessen in the former competition condition, the right hemisphere should be able to exert its linguistic skills fully.

The major purpose of the present study was to test if different effects of word imageability on VF asymmetry would be obtained as a function of increasing memory loads. The following pair of predictions was derived: First, recognition memory differences between HI and LI stimuli would increase as delay time increases because word imageability affects memory performance. Second, if the visual word processing abilities of the right hemisphere is based on word imageability, the above mentioned tendency would be evident in the LVF presentation condition.

Method

Subjects. Forty college students (15 males and 25 females) aged 18 to 23 years were tested individually. They were all self-declared right-handers with normal uncorrected vision.

Stimuli. The stimuli were 76 concrete nouns with high imageability (HI) and 76 abstract nouns with low imageability (LI), each consisting of two *Kanji* characters (above 5.600 or below 3.467 in imageability, and above 5.000 or below 3.667 in concreteness in the scale of Ogawa and Inamura [1974]).

The stimuli were *Kanji* characters drawn in Min-era type of print. Each stimulus was arranged vertically on a 35 mm slide so that it appeared black against a white background. The slides were exposed on a rear-projection screen which was 51 cm in front of the subjects at eye level. Each stimulus subtended a visual angle of 3.37° (1.12° for one *Kanji* character) vertically and 1.12° horizontally, and the distance between the inner edge of each stimulus and the center of the fixation mark (×) subtended a visual angle of 4.16°. The projection field subtended a visual angle of 14.6° vertically and 23.0° horizontally. An example of the pairs of stimuli is shown in Fig. 1.

Each stimulus pair was presented im-

Fig. 1. One example of the stimulus pair used in the present study. In this pair, a left side stimulus was HI noun and a right side stimulus was LI noun.

mediately after the ready signal (⊗) which was presented at the center of the screen for 1 s. The exposure duration of each pair of stimuli and fixation mark (×) was 150 ms and the intertrial interval was 2 s.

Two lists of experimental noun consisted of 76 noun pairs including 4 filler pairs were presented for the running memory span (RMS) task. Generally, in a RMS task, each stimulus is presented twice. In the first presentation of a given stimulus, the correct response is "new" and in its second presentation the correct response is "old". The lag between the first and the second presentation (memory span: number of intervening pairs) varied: In the present study, Lags 0, 2, and 8 pairs were used.

The HI and LI lists consisted of 40 HI and 76 LI stimuli and of 76 HI and 40 LI stimuli, respectively. In the HI list, 36 out of the 40 HI stimuli were presented twice (double presentation with lag), and the remaining 4 HI stimuli and 76 LI stimuli were presented once. Similarly in the LI list, 36 LI test stimuli were presented twice (double presentation with lag), and the remaining 4 LI stimuli and 76 HI stimuli were presented once.

Each pair was composed of one HI and one LI stimulus and was presented bilaterally with a central fixation mark (cross). For example, when a given HI stimulus was displayed in the LVF, a LI stimulus

was displayed in the RVF and vice versa. No pair was used twice. A given test stimulus appeared in the same VF in both the first and the second presentation. That is to say, in each list, half of the 36 test stimuli were presented twice to the LVF while the remaining stimuli were presented twice to the RVF.

Apparatus. A two-channel projector tachistoscope, consisting of two projectors (Kodak Carousal, model B-2) and two electronic shutters (Gerbrands, Model G1169), was used. Rate of presentation and exposure duration of the slides was controlled by a preset digital timer (Takei Co.).

Procedure. The two lists were ordered so that the lag between the first and the second presentation of a given test stimulus was either 0, 2 or 8 presentations. In each list, there were 12 double stimuli recurring after each lag; of these, 6 stimuli recurred at the LVF and the remaining 6 stimuli recurred at the RVF. Each subject was tested either on the HI test list or the LI test list.

In each list, within each successive block of 38 pairs (36 test pairs and 2 filler pairs) an equal number of Lag 8 (8 intervening pairs) occurred. Tests of the remaining lags (0 and 2 intervening pairs conditions) were distributed as evenly as possible throughout the list. Successive runs of more than three new or old stimuli were avoided, and the proportion of the pairs containing the test stimuli to the pairs consisting of only non-target stimuli was same across blocks. In each list, two filler pairs were presented at the top of the list and one filler pair was presented at the end of the list, the remaining filler pair was presented seventh to last in order to regulate the Lag conditions.

Each subject sat facing a rear-projection screen. The viewing distance of 51 cm was held constant by a chin-head rest. Prior to the experimental trials, the subject was told that he or she would see a series of slides successively presented

on the screen and each slide would contain two vertically arranged nouns (composed of two *Kanji* characters) appearing both on the left and right of the central fixation mark. The subject was instructed to say "Yes (old)" if the subject had seen either stimulus of the pair before, and "No (new)" if the subject had not seen either stimulus of the pair before. The subject was also instructed to fixate at the center of the screen as soon as the ready signal (a circled cross; ⊗) appeared at the center of the screen. The subjects were told that keeping to fixate at the center would be the best for making correct responses. Each subject was run individually. For each trial ready signal first appeared at the center of the screen for 1 s. Then each pair of stimuli was projected bilaterally to the LVF and RVF for 150 ms. The intertrial interval was 2 s. After 10 practice trials, which were the same for both experimental groups (HI and LI test stimulus group), but different from those used in the test trial, a total of 76 experimental trials were administered to each subject. Subject's fixation was monitored by the experimenter throughout the experimental session.

Results

There were two measures of recognition memory: Hit rate and False Alarm rate. Hit rate refers to the proportion of stimuli seen before and correctly stated as to have been seen before, and False Alarm rate refers to the proportion of stimuli not seen before but incorrectly stated as to have been seen before. These two measures were calculated separately for each subject under each condition and were used to obtain the Signal Detection Theory measure of memory strength, namely d' , using the tables for this purpose (Elliott, 1964). Table 1 shows the means of Hit rates and d' values for each condition.

The hit rates were subjected to an

Table 1
Mean d' and hit rate in RVF and LVF for two levels of imageability
and three levels of lag

Lag	Level of imageability			
	High		Low	
	LVF	RVF	LVF	RVF
0	1.56 (63.3)	2.77 (90.0)	1.54 (62.5)	2.96 (93.3)
2	1.72 (64.2)	1.79 (74.2)	1.06 (50.0)	1.81 (72.5)
8	1.73 (69.2)	2.15 (75.8)	1.07 (50.8)	1.84 (73.3)

Note. Number in parenthesis indicates the percentage hit rate for that condition.

analysis of variance after being transformed with an arc sine transformation. Separate three-way within-subjects factorial analyses of variance (VF $\times$ Lag $\times$ subjects) on Hit rate and d' were conducted for the results of the recognition memory of HI and LI nouns. Because these two measures produced essentially similar results, for the sake of brevity only the result based upon d' is hereby reported.

The analysis for the recognition memory of HI nouns revealed significant main effects for Lag, $F(2,38)=4.49$, $p<0.05$, and for VF, $F(1,19)=19.41$, $p<0.01$, and a significant Lag by VF interaction, $F(2,38)=7.01$, $p<0.01$. The main effect of Lag reflected a general decline in accuracy as the number of intervening pairs increased from 0 to 8 (2.17 vs. 1.76 vs. 1.94, in d' respectively). Scheffé's test, however, showed only a significant difference between Lag 0 and Lag 2. Stimulus recognition at Lag 0 and Lag 8 was approximately equal. The main effect for VF indicates that overall recognition memory was significantly better in RVF than in LVF ($p<0.01$). The significant VF by Lag interaction was in accord with the predictions of the present study, since in the LVF at each Lag recognition memory was exactly the same, but in the RVF recognition memory decreased dramatically as Lag increased from 0 to 8. Scheffé's test showed a significant RVF

superiority only at Lag 0, but not at Lags 2 or 8.

For recognition memory of LI nouns, the analysis yielded a significant main effect for Lag, $F(2,38)=20.74$, $p<0.01$, and for VF, $F(1,19)=82.13$, $p<0.01$, a Lag by VF interaction was not significant, $F(2,38)=2.17$. The main effect of Lag reflects the fact that recognition memory at Lag 0 was significantly better ($p<0.01$) than at Lags 2 and 8 (2.27 vs. 1.14 and 1.45, respectively), and there was no significant difference between recognition memory at Lags 2 and 8. The main effect of VF shows that overall recognition memory in RVF was superior to that in LVF. Furthermore, one can see that this tendency was greater for recognition memory of LI stimuli than for that of HI stimuli: for HI, mean recognition scores were 1.67 and 2.24 for the LVF and RVF, respectively; for LI, mean recognition scores were 1.22 and 2.22 for the LVF and RVF, respectively.

Discussion

The present study was designed to reexamine right hemisphere linguistic skills with regard to word imageability. The RMS procedure was used because all of the pertinent previous studies have overlooked the involvement of memory processes in this function. Previous studies

employed either an identification task or a lexical decision task, regardless of the findings that referential word meaning (imageability and concreteness) facilitates neither word naming nor lexical decision time but does facilitate memory. It is thus possible that a minimal load on memory in performing these tasks (word naming and lexical decision) contributed to the inconclusive results in the previous studies.

Based on this reasoning, it was assumed that because word imageability affects memory processes, recognition memory differences between HI and LI stimuli would increase as time lag increases, and that if the right hemisphere linguistic skill is imagery-based, this tendency would be evident in the LVF presentation condition. In other words, differential effect of word imageability on VF asymmetry should be obtained as a function of increasing memory load.

This assumption was basically supported by the following results: (1) When the test stimulus reappeared immediately after its first presentation, clear RVF (left hemisphere) superiority was found regardless of stimulus imageability, (2) however, when the test stimulus reappeared after 2 or 8 lags, RVF superiority for HI stimuli was completely diminished, but not for LI stimuli. That is to say, the effect of word imageability on recognition by right hemisphere was more apparent in the condition which was dependent on memory.

Previously reported conflicting data concerning the effect of concreteness and imageability on right hemisphere word processing can not necessarily be explained within the framework of the above mentioned hypothesis. But we can notice that most of the previous studies which reported a positive effect of concreteness or imageability employed bilateral presentation and an identification task (Ellis & Shepherd, 1974; Elman, Takahashi, & Tohsaku, 1981; Hines, 1976, 1977; Kelly & Orton, 1979; McFarland, McFarland,

Bain, & Ashton, 1978). This kind of task and presentation procedure are most dependent on memory processes than a lexical decision task, a matching task, or a unilateral presentation procedure.

Moreover, from the results of this experiment, some interesting suggestions regarding right hemisphere linguistic skills have emerged. The first suggestion could be formed from the results of Lag 0. In this experimental condition, very similar patterns of VF differences were obtained regardless of stimulus imageability. Specifically, at Lag 0 LI stimuli presented to the LVF were recognized equally well as HI stimuli presented to the LVF. If right hemispheric word recognition is based only on imagery, then even if RVF superiority is obtained for both HI and LI stimuli at Lag 0 (because of the minimum memory load of this condition), since it does not mean Zero memory load of this condition the RVF superiority for LI stimuli should be greater than that for the HI stimuli. However, this was not the case in this study.

The Lag 0 condition in this study is similar to a word matching task. Gibson, Dimond, and Gazzaniga (1972) revealed that a LVF superiority for a word matching task even though the subjects were unable to give verbal reports of the words they were matching. They interpreted their results as showing that because a word matching task can be performed by comparing the physical configurations of both words, the visuo-spatial ability of the right hemisphere aided in performing this task. This assumption, in terms of a lexical access route through physical configuration, is supported by clinical data. Using commissurotomy patients, Zaidel (1978) showed that the right hemisphere can recognize words by their physical configuration. Zaidel also concluded that word recognition through physical configuration in the right hemisphere should be something more abstract than associating the meaning of word with a par-

ticular sensory template.

The results of Lag 0 condition in the present study can be explained within this context. Presumably, a word presented to the LVF is initially recognized by its physical code, and subsequently by its associative imagery code. In short, it appears that the right hemisphere recognizes a word in two ways; first by a physical code and then by an imagery code.

A support exists for this suggestion of two independent ways of word recognition by the right hemisphere. Replicating the Sternberg memory scanning task for each hemisphere, Seamon (1974, experiment 2) found a faster RT to the target stimuli (word) exposed to LVF (right hemisphere superiority) in spite of the instruction for the subjects to use verbal rehearsal strategy to remember the words in each memory set (varying in size from one to three words). He interpreted this result as showing that since speed was a factor in this task, the subjects might have simplified the task by responding on the basis of the physical aspects of the stimuli (physical code) and this simplification of the task should lead right hemisphere superiority.

To confirm this interpretation, the experiment in which the target stimulus was changed from a word to a picture was conducted (Seamon, 1974 experiment 3). It was expected that if imagery is a part of the visual processing system and thus it is closely related with a function of right hemisphere, the use of a picture target results in right hemisphere superiority in a group of subjects instructed to use imagery to remember the words in a memory set. On the other hand, for a group of subjects instructed to use verbal rehearsal strategy, it was expected that because an introduction of a picture as target stimulus would make it impossible to compare the target stimulus with each item in memory set via physical code, the picture target should be transformed into verbal code and this transformation would

lead a left hemisphere superiority.

The result was completely congruent with these predictions. The subjects who used imagery coding strategy showed significantly faster RT to the target directed to the right hemisphere than that to the left, but the subjects who used verbal rehearsal strategy showed entirely reverse pattern of the result. Taken together, it could be inferred from these results that word stimuli can be stored in a short-term memory set by one of three types of memory codes; physical code, imagery code and verbal code, and the former two types of code are closely related to the function of the right hemisphere. The result of the present study seems to be consistent with this inference.

The second suggestion derived from the present study is that right hemisphere recognition capability of HI words is related to its storage or retrieval processes rather than its initial encoding process. In the present study, there were no VF difference for the recognition memory of HI nouns either at Lag 2 or at Lag 8. This finding is attributable to the fact that recognition memory of HI stimuli presented to the LVF was less sensitive to the increase of lag than that of HI stimuli presented to the RVF. In fact, recognition memory of HI stimuli presented to the RVF was extremely impaired both at Lag 2 and at Lag 8 as compared with the performance level at Lag 0. In contrast, the recognition memory of LI stimuli decreased proportionately in both VFs as the lag increased, so that significant RVF superiority was obtained consistently in all Lag conditions. These results can be interpreted as showing that the HI stimuli presented to the LVF (right hemisphere) could be stored (and perhaps retrieved) effectively by use of associative imagery codes. In contrast, the LI stimuli presented to the LVF could not be stored by such an associative code, so that recognition memory of the LI stimuli presented to the LVF would be

inferior both at Lag 2 and at Lag 8 when compared with that of Lag 0.

This interpretation is also consistent with the view that imagery itself shows a strong resistance to interference. Paivio (1972) pointed out that imagery is the source of distinctiveness and resistance to interference, and that imagery is generally less susceptible to interference effects than are verbal processes. In addition, it is possible that because both HI and LI stimuli presented to the RVF can be stored by using a verbal code, the retrieval process of the left hemisphere would suffer from a greater inter-stimulus interference than the retrieval process of the right hemisphere where only HI stimuli can be stored by means of associative imagery codes.

In summary, the present study supported the view that the right hemisphere of normal intact brain is able to process word stimuli by using associative imagery code. And this linguistic skill of the right hemisphere became apparent only when memory task was used. In addition, effect of memory load indicates that the laterality in recognition memory of HI and LI words primarily reflects storage processes rather than initial encoding processes of the right hemisphere. However, further investigation is necessary to test the validity of this interpretation with regard to right hemisphere word processing ability.

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