Right Hemisphere Superiority in Recognition of Random Dot Patterns and the Effect of Memory Factor

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RIGHT HEMISPHERE SUPERIORITY IN RECOGNITION OF RANDOM DOT PATTERNS AND THE EFFECT OF MEMORY FACTOR

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Two experiments were conducted as regard to the laterality differences in the recognition of random dot patterns. In experiment I, left field superiority in the recognition of random dot patterns was obtained under haploscopic viewing condition. In addition, greater inter-half-field difference was shown between 2 nasal hemiretinas than between 2 temporal hemiretinas. In experiment II, effects of memory factor were examined by varying the time interval between the test stimuli and the choice display from 0.5 to 5.0 sec. Significant inter-half-field difference was obtained only at the time interval of 1.5 sec. The results were interpreted as indicating an important role memory factor plays in the laterality differences in visual perception.

INTRODUCTION

As is well known, there is now substantial evidence of left hemisphere dominance for language abilities, even in the majority of left handers. There is also a growing body of evidence that the nonverbal visuo-spatial informations are mediated primarily by the right hemisphere. Neurosurgical studies showed that the patients with lesions in the right hemisphere failed in some kinds of visuo-spatial performances (Benton *et al* 1975, De Renzi & Spinnler 1966, De Renzi *et al.* 1969, Kimura 1963, Newcombe & Russell 1969, Tayler & Warrington 1973, Warrington & James 1967 a, b, Warrington & Rabin 1970). On the other hand, the specific function of the right hemisphere in normal subjects has been studied with psychological methods. Kimura (1966) presented verbal and nonverbal stimuli to normal *S*s by means of a tachistoscope and showed that letters were more accurately identified in the right visual field (RVF), and that the enumeration of certain nonalphabetical stimuli was more accurate when they appeared in the left visual field (LVF) than when they appeared in the RVF. In subsequent studies, Kimura *et al.* found LVF superiority for dot localization (Kimura, 1969) and for depth perception (Durnford & Kimura, 1971), while there was no difference between the fields with respect to abstract or familiar geometric forms (Bryden 1960, Bryden & Rainey 1963, Kimura 1966, Terrace 1959). Kimura's findings are supported by several other studies which used as nonverbal stimuli, various slant lines (Fontenot & Benton 1972, Honda 1975), photographs of faces (Gilbert & Bakan 1973, Hilliard 1973), solidly painted random patterns (Fontenot, 1973) and so on. These results are interpreted as confirming the hypothesis about the visuo-spatial function of rihgt minor hemisphere, since when *S* fixates a central position of visual field, the stimuli that appear in the LVF project directly to the right hemisphere, whereas the stimuli in the RVF project to the left hemisphere.

In this study, random dot patterns were used as test stimuli. In experiment I, we examined the accuracy of the recognition of random dot patterns tachistoscopically exposed in the LVF or the RVF in normal right-handed *S*s. The major purpose of the experiment I was to test the hypothesis that the nonverbal visuo-spatial stimuli such as random dot patterns would be recognized more accurately when presented in the LVF than when presented in the RVF. The hypothesis was partly derived from Mckeever & Huling's finding that when *S*s were required to draw designs 3, 4, 5, 7 and 8 of the Bender Visual-motor Gestalt Test after brief design exposure, then designs 3 and 5, both composed of dots, were drawn more accurately when these were exposed in the LVF than in the RVF, while solid line designs (4, 7, 8) showed no interfield difference (Mckeever & Huling, 1970).

A second purpose of the present study was to investigate the role of memory factors in producing perceptual asymmetry. Although many a sutdy conducted on asymmetry in perception, there was little or no study which was seriously concerned with the possible effects of memory. In experiment II, random dot patterns were presented either in the LVF or in the RVF, and after a delay of 0.5–5 sec, to the *S* was shown a choice display consisting of 2 dot patterns and he was required to indicate which was the previously presented target stimulus. The difference in accuracy between the fields as a function of the retention interval was examined.

Experiment I

The aim of this experiment was to examine the accuracy of the recognition of the random dot patterns which were briefly exposed in the LVF or the RVF under haploscopic monocular viewing condition.

Method

Subjects: Ten right-handed (9 male and 1 female) students, ranging in age from 22 to 27 years, served as *S*s voluntarily. Each *S* had normal and approximately equal acuity in each eye. Of the 10 *S*s, 6 *S*s demonstrated the dominance of the right eye, and 4 *S*s the dominance of the left eye.

Stimuli: Two sets of test stimuli were used in this experiment. Each set consisted of 8 random dot patterns (Fig. 1). Of these 8 dot patterns, 4 dot patterns were mirror images of the remaining 4 dot patterns. Each random dot pattern was made by scattering 7 black dots (1.5 mm in diameter) within an imaginary 2.5 cm × 2.5 cm square. These test stimuli were drawn on a white card in black ink, and presented haploscopically with a modified 3 channel tachistoscope to the RVF or the LVF of each eye separately.

Procedure: The experiment was conducted under haploscopic viewing condition,

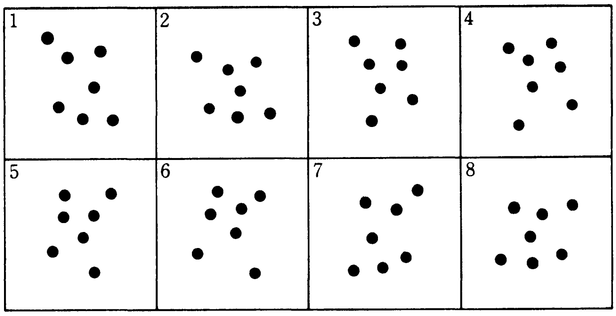

Fig. 1. An example of stimulus set used in experiment I.

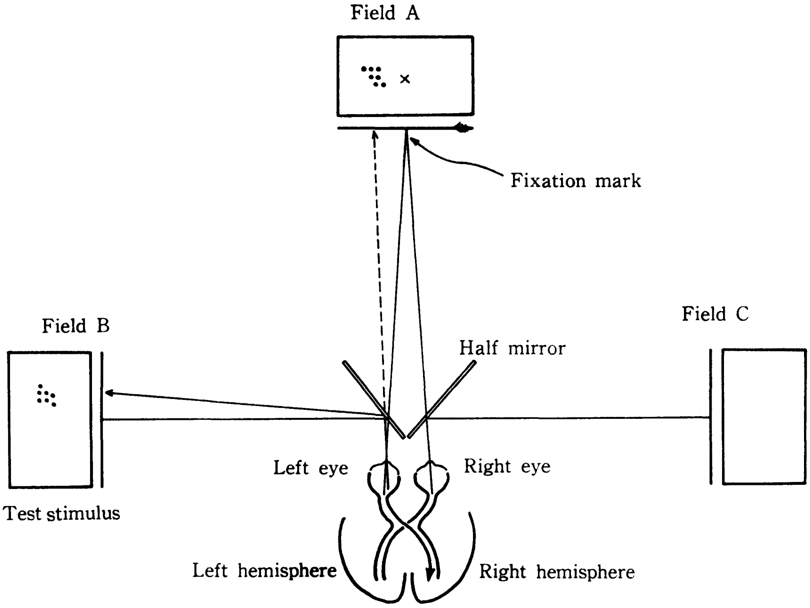

Fig. 2. Haploscopic viewing condition.

in which a test stimulus was presented to the right or left eye of the *S* separately (see Fig. 2). The *S* was required to fixate a small cross (×) placed at the center of the field A (12.4 degrees high and 20.5 degrees wide). The exposure field was approximately 65 cm from the *S*'s eyes. The small cross was presented for 2500 msec. Immediately after the disappearance of the small cross, test stimulus was exposed for 75 msec to the LVF or to the RVF of the field B or C. The test stimuli which appeared in the field B were projected only to the *S*'s left eye, and those in the field C were projected only to the *S*'s right eye. In this situation, *S* saw the test stimuli in field B or C as if they had appeared to the LVF or the RVF of the field A, and moreover *S* was not able to know to which eye the test stimulus was presented. Each test stimulus subtended a horizontal visual angle of 2° and was centered on a point 1.5° to the left or to the right of the fixation. The *S* was instructed to fixate the small cross until the test stimuli had been exposed, and not to predict the visual half-field to which the test stimulus was going to be presented. After each stimulus presentation, the *S* was required to choose, from a visual display of the 8 different dot patterns, the stimulus that was presented to him. *S* responded by saying the figure attached to each dot pattern on a visual display which was placed in front of him. Each dot pattern was presented only once to the LVF and RVF of each eye. After the presentation of all stimuli of the stimulus set A, another set of dot patterns, i.e., stimulus set B were presented to *S*, so the test stimuli were presented 32 times in all to each visual field.

Results

The results from 10 *S*s are shown in Table 1. Fig. 3 represents the percentage of correct responses in the LVF and the RVF of each eye separately. Random dot patterns were recognized more accurately in the LVF than in the RVF in both eyes. The expected LVF superiority was statistically significant only for the left eye ($p<.025$, one-tailed signed rank test), and there was no significant difference for the right eye. Although the recognition scores of the left eye seem to be higher than those of the right eye in both visual half-fields, the differences between the 2 eyes were not statistically significant.

Table 1. Mean ($\bar{X}$), standard deviation (SD) and percentage (%) of number of correct responses in experiment I. N=10.

	Left eye		Right eye	
	LVF	RVF	LVF	RVF
$\bar{X}$	11.1	9.7	10.1	9.2
SD	2.5	1.3	2.7	2.0
%	69.4	60.6	63.1	57.5

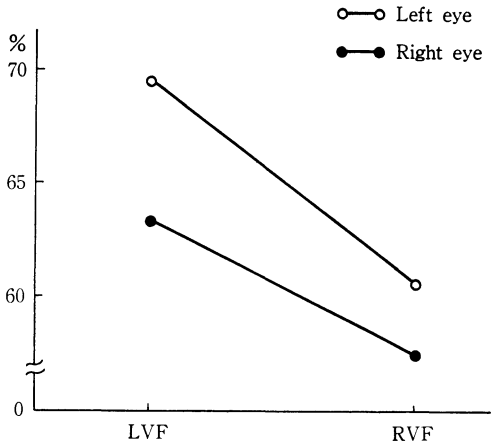

Fig. 3. Percentages of number of correct responses in the LVF and the RVF of each eye.

By the way, it is well known that the nasal hemiretina of each eye projects, through crossed optic tract, to the contralateral visual cortex, while the temporal hemiretina of each eye projects, through uncrossed optic tract, to the ipsilateral visual cortex. In Fig. 4, the laterality differences in nasal and temporal hemiretinas are shown separately. A greater interfield difference was produced between the 2 nasal hemiretinas, i.e., the LVF of the left eye and the RVF of the right eye. The interfield difference was highly significant ($p<.005$, one-tailed signed rank test). On the other hand, there was no significant difference between the 2 temporal hemiretinas, i.e., the RVF of the left eye and the LVF of the right eye.

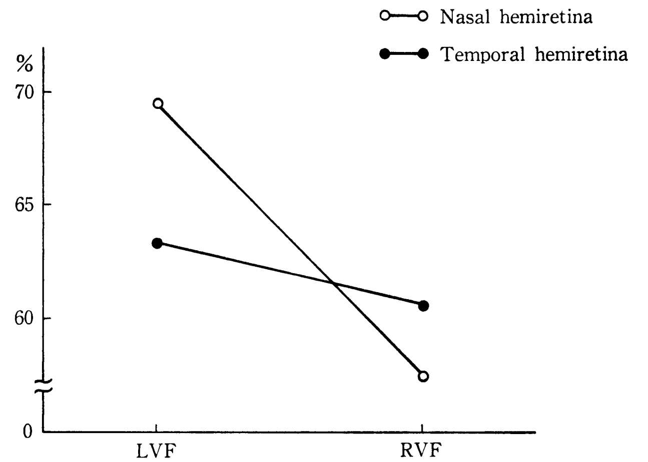

Fig. 4. Comparison of laterality differences in nasal and temporal hemiretinas.

Experiment II

Experiment I demonstrated a LVF superiority for the recognition of random dot patterns. The experimental procedure was to present test stimuli either to the LVF or to the RVF and then to ask the *S* to choose the stimulus that he had just seen from an array of several stimulus patterns. It is notable, however, that this experimental paradigms do not enable us to distinguish between the perceptual and the retentional aspects, since the time intervals between the presentation of the test stimulus and the response of *S* vary with trials. In the second experiment an attempt was made to examine the role of memory factor in the LVF superiority for the recognition of random dot patterns, by varying the time interval from 0.5 to 5 sec systematically, and the choice display which was performed in order to reduce the length of time required for *S* to choose his responses, contained only two dot patterns.

Method

Subjects: *S*s were 9 right-handed (8 males and 1 female) students with normal or corrected vision. Their age ranged from 22 to 27 years.

Stimuli: Sixteen random dot patterns were used as test stimuli. These patterns were made by scattering 7 dots within an imaginary square (3 cm×3 cm). Of the 16 patterns, 8 patterns were mirror images of the remaining 8 patterns. As a matter of course, this treatment was done in order to counterbalance the effects of unintended directionality of each stimulus patterns. The original 8 patterns consisted of 4 pairs of highly similarity. As will be described later, the choice displays for each target stimulus contained these pairs of dot patterns.

Procedure: A 3 channel tachistoscope was used to present the test stimuli and the choice displays. The background and exposure fields were approximately 23 cm × 14 cm, subtending a horizontal visual angle of about 20.5° at the retina. The *S* was asked to look at a fixation mark (a small cross, +) which appeared at the center of the visual field for 2500 msec. Immediately after the disappearance of the fixation mark, the target stimulus was exposed either in the LVF or in the RVF for 80 msec. Each stimulus subtended a horizontal visual angle of about 1.8° and centered on a point 1.8° to the left or to the right of a central fixation mark. After a delay of 0.5, 1.5, 3 or 5 sec, the *S* was shown a choice display on which 2 dot patterns were vertically ranged one above the other to eliminate horizontal scanning effects. The choice display was shown in the visual half-field contralateral to the field where the target stimulus had been shown, so as to prevent the choice display from the visual blocking by target stimulus. The distance from a fixation mark to the center of the vertically placed 2 dot patterns was about 2 cm, subtending a horizontal visual angle of about 1.8°. The *S* was required to indicate which of the paired stimuli in the choice display was the previously presented target stimulus, by saying "above" or "below". Fig. 5 represents the experimental paradigm. Eight target stimuli were presented successively in the LVF and the RVF in random order, and after a fixed delay interval the choice display was shown. And then the next 8 target stimuli were tested under another delay interval condition. In this way, 16 dot patterns were tested in each visual field under each of the 4 delay interval conditions, therefore each *S* was given a total of 128 stimulus presentations (16 dot patterns × 2 visual fields × 4 delay interval conditions).

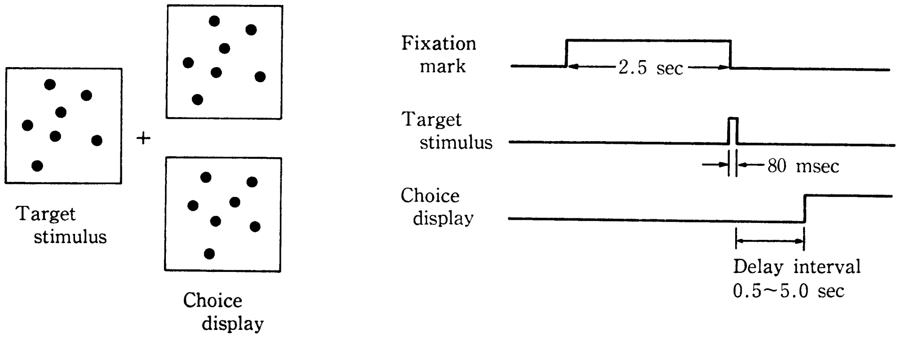

Fig. 5. Experimental paradigm of experiment II.

Results

Table 2 presents the means, standard deviations and percentages of correct responses in the LVF and the RVF for 4 delay interval conditions separately. Fig. 6 shows the percent correct recognition in the LVF and the RVF as a function of the retention interval. Random dot patterns were recognized more accurately in the LVF than in the RVF under all of the delay interval conditions. Table 3 presents the results of statistical treatments for the difference between 2 visual fields. Statistically significant difference between 2 visual fields at the same delay interval was shown only at the 1.5 sec delay interval. There was no significant difference between 2 visual fields under the delay interval conditions of 0.5, 3, and 5 sec. The performance in the LVF at the 1.5 sec delay interval was superior to that in the RVF at all delay intervals. Besides, there was statistically significant difference between the performance level in the LVF at the 1.5 sec delay interval and that in the same visual field at the 5 sec delay interval.

Table 2. Mean ($\bar{X}$), standard deviation (SD) and percentage (%) of number of correct responses in each visual field for 4 delay interval conditions. N=9.

Delay Interval	0.5 sec		1.5		3.0		5.0	
Visual Field	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF
$\bar{X}$	12.9	11.7	13.8	12.3	12.3	11.8	12.2	11.4
SD	1.8	1.8	1.3	0.9	2.5	1.5	0.9	1.6
%	80.5	72.8	86.1	77.1	77.1	73.6	76.4	71.5

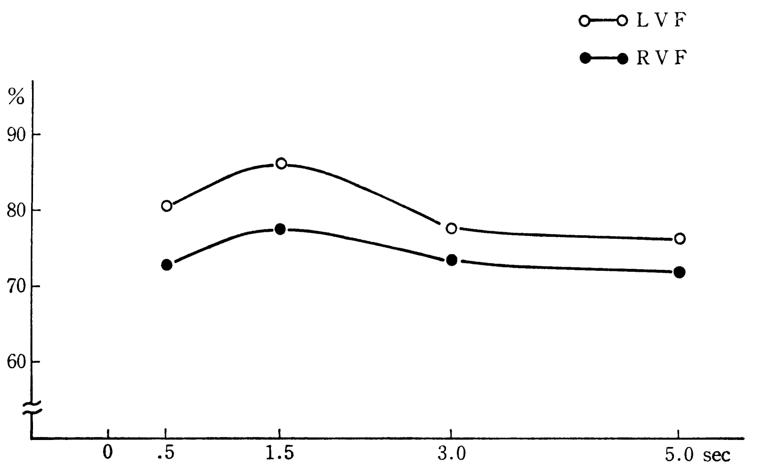

Fig. 6. Percent correct recognition in the LVF and the RVF as a function of the retention (delay) interval.

Discussion

In experiment I, it was confirmed that the recognition of random dot patterns

Table 3. Summary of statistical treatment for the difference between 2 visual fields (two-tailed t test for correlated means). NS: nonsignificant.

		Left Visual Field			
	Delay Interval	0.5	1.5	3.0	5.0
Right Visual Field	0.5	NS	$p<.025$	NS	NS
	1.5	NS	$p<.025$	NS	NS
	3.0	NS	$p<.025$	NS	NS
	5.0	$p<.025$	$p<.01$	NS	NS

was more accurate in the LVF than in the RVF. The results in this study are consistent with those of other studies which were conducted with various types of nonverbal stimuli (Kimura & Durnford, 1974).

According to Subjects' introspective reports after experiment, they performed the task by identifing either the visuo-spatial relationship among two or more dots or the contour of each dot pattern. In regard to the former case, for example, the S often reported that in order to discriminate the dot patterns, he paid his attention particularly to the visuo-spatial relationship between 2 dots placed on the upper side of each dot pattern, and used as a cue the direction of the line drawn through the 2 dots. This means that the LVF superiority shown in this study is closely related to the LVF superiority in the recognition of line orientation (Honda, 1975). The role of contour of each dot pattern in identifing the target stimuli becomes evident on the analysis of errors. The S often made an error by indicating a pattern which showed a contour very simillar to the target stimulus.

Although the LVF superiority was shown in both eyes, the statistically significant difference between the 2 visual half-fields was shown only in the left eye. On the other hand, the recognition score of the left eye tends to be superior to that of the right eye in both visual fields. The difference between the 2 eyes mentioned above cannot be adequately accounted for so far, and yet seems to be closely related to the functional difference in the optic tracts or in the heniretinas of each eye.

As shown in Fig. 4, a greater interfield difference was produced by the nasal hemiretinas of the right and the left eyes which project, through crossed optic tracts, to the contralateral visual cortex. The greater interfield difference between the nasal hemiretinas was found also in the recognition of line orientaton (Honda, 1975). The nasal superiority has been found in the recall of digit (Bower & Haley 1964, Crovitz & Lipscomb 1963, Sampson & Spong 1961, Sampson 1969), in color rivalry (Crovitz & Lipscomb, 1963) in the reproduction of complex patterned stimuli (Harcum & Dyler, 1962) and in simple reaction time (Poffenberger 1912, Maddess 1975), whereas temporal superiority has been found under monocular noncompetitive situation (Marcowitz & Weitzman 1969, Neil *et al.* 1971). These findings suggest that there is functional difference between the crossed (nasal) and uncrossed (temporal) optic tracts.

However, the greater interfield difference by the nasal hemiretinas shown in this study seems to be explained not by these suggestion mentioned above, but by a hypothesis that the nasal hemiretinas (i.e., crossed optic tracts) are more closely related to the specific asymmetric functions of the right and left hemispheres than the temporal hemiretinas (i.e., uncrossed optic tracts).

In experiment II, it was shown that the performance level in the recognition of random dot patterns changed as a function of the delay intervals, and that the significant visual half-field difference was obtained only at the 1.5 sec delay interval. As shown in Fig. 6, the performance level at 0.5 sec delay interval was inferior to that at 1.5 sec delay interval. However, the difference did not reach a statistically significant level. This is ascribed to the inter-individual differences found in the performance level at the 0.5 and 1.5 sec delay intervals. As regards the performance level in the LVF, for example, 5 *S*s showed the highest accuracy at the 0.5 and 1.5 sec delay intervals, and reduced the accuracy as the interval increased, whereas 4 *S*s showed considerably low performance level at the 0.5 sec delay interval. Therefore, the target stimuli did not seem to have been processed in the same way by the *S*s at the 0.5 sec delay interval.

It seems that the relatively low performance level on either side of the peak at 1.5 sec delay interval cannot be ascribed to the same mechanisms. The low performance level at the shortest 0.5 sec delay interval is probably due to the failure of the *S* in being ready for the comparison of the target stimulus and the choice display. The target stimuli are perceived as a visual information and then have to be retained so that they may be compared with a choice display. The information immediately after the presentation may be retained as the so-called "visual iconic memory" (Sperling, 1960). However, the duration of iconic memory is thought to be within about from 1/4 to 1 sec (Haber & Hershenson 1973, Sperling 1960). If this is true, the peak in performance level at 1.5 sec delay interval and the relatively low performance level at the 0.5 sec delay interval do not seem to be explained in terms of a visual iconic memory. On the other hand, the target stimuli may be influenced by the effects of the visual masking by the presentation of the choice display. That is, the fragile memory trace of the target stimuli may be destroyed by the choice display which follows after short delay interval, in spite of the fact that the choice display appeared in the visual field contralateral to the field where the target stimuli were exposed. However, if this is true, the results in this study suggest that each *S* required different time interval for effective visual masking, since several *S*s showed relatively high level of performance even at the 0.5 sec delay interval. It seems reasonable to think that the memory trace of the target stimuli is required to consolidate so as to be compared with the choice display, and that the ability to consolidate varies with subjects. The decrement of the performance level after the delay time of 3 sec seems to be closely related to the degradation of the memory trace of the target stimuli. Within this delay intervals, *S*s showed almost the same pattern of performance.

The significant LVF superiority shown only at the 1.5 sec delay interval suggests that the memory factor plays an important role in the experimental paradigm of visual matching employed in this study. As shown in Fig. 6, however, the recognition curve of the LVF was almost the same with that of the RVF. That is, the highest performance level was achieved at the 1.5 sec delay interval in both visual fields. This means hat the teffects of memory factor on the recognition accuracy don't wholly depend on the visual field where the target stimulus was projected. Dee & Fontenot (1973) examined the effects of memory factor on the visual half-field difference in the perception of Vanderplas & Garvin's (1959) random pattern. The LVF superiority was obtained only at the 10 and 20 sec delay intervals, while there was no field difference at 0 and 5 sec delay intervals. The results of our study cannot be compared directly with those of Dee & Fontenot, since there are some methodological differences between the 2 studies. The chief difference between them is that they dealt with different temporal aspects of the pattern recognition.

In this study, we examined the effects of memory factor on the visual field difference in the recognition of random dot patterns, and showed the important role of memory factor in this type of experimental paradigm. In conclusion, the results suggest that the visual field difference reflects not only the perceptual aspects but also the mnemonic aspects of the visual information processing, since, if the difference in performance level of the right and the left visual fields can be ascribed to the perceptual or sensational level in the visual information processing, then it is hardly possible that we obtain clear effects of the delay intervals.

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