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Visual localization in patients with unilateral brain disease[1]

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SYNOPSIS The accuracy of localization of briefly exposed single dots and pairs of dots was assessed in patients with lesions of the left and right hemispheres and in control patients without history or evidence of brain disease. A remarkably high frequency of impaired performance was found in the patients with right hemisphere lesions. The performance of the patients with left hemisphere lesions was comparable with that of the control patients. Visual field defect was associated with defective localization in the right hemisphere group but not in the left hemisphere group. Aphasic disorder and age were not related to performance level. The relationship of the findings to those of previous studies of visual localization in patients with unilateral brain disease is discussed.

The concept that, at least in right-handed subjects, the right hemisphere plays a distinctively important role in mediating the spatial aspects of perception is one that is by now widely accepted (*cf.* Hécaen, 1972; Joynt and Goldstein, 1975). Evidence supporting this generalization has come, not only from study of visual performances such as constructional praxis (Benton, 1967; Warrington, 1969), spatial orientation (De Renzi *et al.*, 1971) and the discrimination of line orientation (Warrington and Rabin, 1970; Benton *et al.*, 1975), but also from analogous study of auditory and tactile performances requiring spatial judgments (Shankweiler, 1961; Carmon and Benton, 1969; Fontenot and Benton, 1971). The results of investigations on normal subjects, in whom a left visual field superiority (Fontenot and Benton, 1972) and a left-hand superiority (Benton *et al.*, 1973) in performance is found, and those on patients with focal brain disease are in accord in their indications of the 'dominance' of the right hemisphere for these tasks.

Given these findings, it seems curious that the question of hemispheric dominance for the identification of location or position of an object in the visual field, a performance that obviously involves an important spatial component, remains unresolved. Warrington and Rabin (1970) studied visual localization with a perceptual matching task. Two cards containing single dots were presented in a vertical array either simultaneously or successively and the patient judged whether or not the position of the dots was the same on both cards. With 24 trials, the mean, error score of 3.5 for the right hemisphere damaged patients was significantly higher than the very similar mean error scores of 2.3 and 2.1 for the left hemisphere damaged and control groups respectively. Patients with right parietal lesions showed the most severe impairment making a mean of 4.1 errors. The relatively low mean error scores of all the groups suggest that many patients must have made perfect or near-perfect performances. Thus the question may be raised whether a more difficult localization task would disclose more impressive differences between the groups.

A different procedure for studying visual localization was used by Ratcliff and Davies-Jones (1972) who measured the extent of error in localizing point stimuli on a projection perimeter. Patients were instructed to indicate the position of the stimulus by touching it with their index

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finger while fixating gaze on a central point. The hand ipsilateral to the eye being tested was used, except when there was sensorimotor loss in the arm contralateral to the lesion and the hand ipsilateral to the lesion was then used. Defective performance, defined as an error in localization greater than that of any control subject in any quadrant, was associated with posterior parietal, posterior temporal, and posterior occipital lesions in either hemisphere, patients with right- and left-sided lesions showing similar impairment. None of the patients with anterior lesions showed defective localization. Grossly defective performance was defined as a greater mean error in any contralateral quadrant than in any corresponding ipsilateral quadrant by any patient. About 45% of the patients with posterior lesions were grossly defective by this criterion. Of these patients, only 46% had visual field defects as compared with 81% for the rest of the patients with posterior lesions. Visual field defects were evidently not a concomitant of poor visual localization. In general, lesions producing gross impairment in localization were situated in the upper part of the parietal lobe of either hemisphere.

Thus the outcomes of the studies of Warrington and Rabin and of Ratcliff and Davies-Jones lead to different conclusions about the role of the right hemisphere in subserving the visual localization of points in space. A possible explanation for the discrepancy in findings is the obviously different procedures utilized in the two studies. The pointing responses made by the patients of Ratcliff and Davies-Jones assess what has been called 'absolute' localization—that is, of a stimulus in relation to the observer. In contrast, the 'same-different' judgements made by the patients in the study of Warrington and Rabin are examples of 'relative' localization—that is, perception of the spatial relations between two stimuli or comparison of the loci of two stimuli in relation to their respective boundaries (*cf.* Benton, 1969).

Analogous research has been undertaken with normal subjects with similarly inconsistent results. In these studies, dot stimuli are presented unilaterally in the left or right visual fields for very brief durations and more accurate recognition in one visual field is interpreted as indicating dominance of the hemisphere contralateral to that visual field. Left visual field superiority (Kimura, 1969), right visual field superiority (Pohl *et al.*, 1972) and no difference between the fields (Bryden, 1973) have been reported by different investigators. Again, procedural variations in the studies may account for the different findings. However, analysis of these studies directed towards defining the possible effects of such variables as use of a fixation dot, shape of the stimulus field, or the presence of borders in the pre-exposure field does not generally support the idea that these procedural variations are important determinants of the discrepant visual field effects.

Fixating on a central dot rather than staring at a blank screen served only to increase the overall accuracy of localization in the study of Pohl *et al.* (1972). Variations in the shape of the stimulus regions and the presence or absence of borders around these regions have produced contradictory field effects. Pohl *et al.* (1972) used male subjects and single dots appearing in positions forming square unbordered regions in each field and found right visual field superiority. A similar experiment with rectangular stimulus regions produced no visual field superiority for males and females in the presence of a significant right visual field superiority for letters (Bryden, 1973). Kimura (1969) presented dots in square bordered regions in each visual field. Simultaneous exposure of three dots produced no field effects. Single dots produced a left visual field superiority for males but not for females. The finding for males was not confirmed by Pohl *et al.* (1972), who reported no visual field superiority in a similar experiment with square stimulus fields. Kimura (1969) also positioned single dots in a circular bordered region centred in the entire visual field and found a clear left visual field superiority for both males and females. Although the shape of the stimulus region here appears to be a determinant of visual field differences, it should be noted that the change from a square to a circular region also meant a change in the alignment of stimulus positions. With square and rectangular regions, the dot positions were always aligned in rows and columns, while positions in the circular field were aligned along radii. It is impossible, then, to make a definitive statement about the effects of this variable or about the effects of bordering the stimulus regions. In fact, the argument that a border around the stimulus region in the pre-exposure field is a necessary condition for producing a left visual field superiority for localization is questionable. In tachistoscopes the visual fields are not very large and have black edges which could be used by the subject for localizing stimuli in space.

Thus the findings for both patients with brain damage and normal subjects with respect to a possible hemispheric effect in this simple performance have been inconsistent. On the other hand, the studies of Warrington and Rabin (1970) and Ratcliff and Davies-Jones (1972) agree in their emphasis on the importance of the integrity of the posterior parietal lobe in the mediation of this performance. The purpose of the present study was to determine whether the performances of patients with unilateral brain disease on a more demanding visual localization task than is usually employed might disclose stronger evidence of hemispheric asymmetry of function. The level of difficulty of the task was augmented in two ways: (1) the duration of the stimulus exposure was reduced to 300 ms; and (2) the patient was required to identify the location of simultaneously exposed pairs of dots, as well as of single dots.

METHOD

SUBJECTS Right-handed patients from the University of Iowa Hospitals and clinics participated in the study. Twenty-two patients with no history or evidence of brain disease served as controls. Twenty-two patients with left hemisphere lesions and 21 patients with right hemisphere lesions were taken from neurology services. The presence of unilateral lesions was established by clinical examination, angiography, brain scan, and computerized axial tomography.

The three groups of patients did not differ statistically with respect to age. The mean ages of the control, left and right hemisphere groups were 49 years (SD = 15.3), 52 years (SD = 13.2), and 55 years (SD = 11.4) respectively. The control group consisted of 12 men and 10 women. The left hemisphere group contained 12 men and 10 women, while the right hemisphere group contained 16 men and six women. A diagnosis of cerebrovascular disease was assigned to 48% of the left hemisphere group and 50% of the right hemisphere group. The second most frequent diagnosis of neoplasm accounted for 33% of the left hemisphere group and 45% of the right hemisphere group, all of whom were tested before surgery.

APPARATUS A three channel Scientific Prototype tachistoscope, Model GB, was used. The exposure fields were 16 cm horizontally and 11 cm vertically. A blank white card was illuminated in one field at about 69.1 cd/m² except during presentation of stimuli in the second field or the response card in the third field at about 49.7 cd/m².

STIMULI Dots approximately 2 mm diameter and presented at a distance of 123 cm were drawn with India ink on white cards. The dots on the response card filled a region approximately 8.5 cm by 8.5 cm.

PROCEDURE The patient was seated directly in front of the tachistoscope screen and was told that a dot drawn on a stimulus card displayed in the experimenter's hand would appear in the viewer for a very short time. The patient positioned his chin on a chinrest and stated whether or not he saw the dot now exposed for 300 ms. A report of the presence of the dot was followed by the instruction that a display of numbers would appear after the dot. The response card was then presented (Fig. 1). The patient read the numbers in the upper left, upper right, lower left, and lower right corners (1, 4, 22, and 25 respectively), indicated by the experimenter in random order to demonstrate perception of the entire stimulus field as

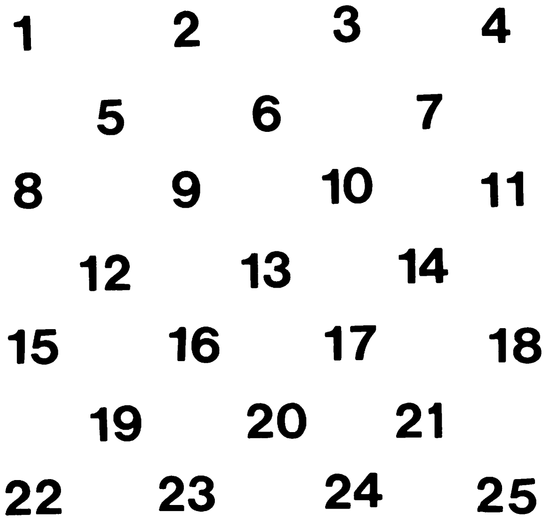

FIG. 1 *Multiple choice card on which dot positions were identified by the patient.*

well as comprehension of the instructions. The patient was told that the dot had appeared in the same position as one of the numbers on the response card. The dot was presented again for 300 ms followed by the blank field for two seconds and the response card for six seconds. The patient was then asked to give the number that was in the same place as the previously presented dot.

Five patients did not understand the task, even with a repetition of the instructions and a second practice trial, and were excluded from the study. Two aphasic patients, who could not say the numbers,

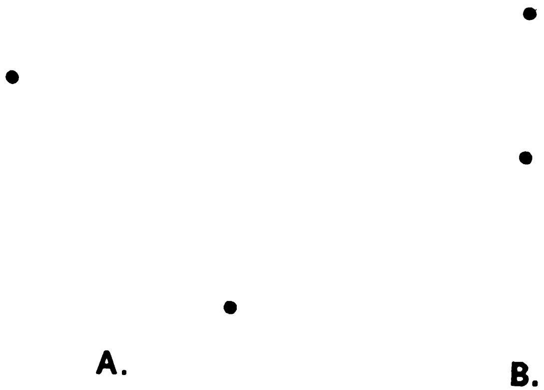

FIG. 2 *Examples of double dot stimuli:* A: *positions 12 and 24;* B: *positions 9 and 16 as shown on the multiple choice card.*

were permitted to point to the appropriate numbers on another response card displayed to the left of the tachistoscope. Their ability to complete the task with this procedure was first tested by having them point to numbers spoken by the experimenter.

The actual experiment consisted of the presentation of a single dot in nine of the 25 positions designated on the response card or the simultaneous presentation of two dots in 18 of the 600 available pairs of positions (Fig. 2). The procedure for both tasks was identical with that for the practice stimulus except that the patient gave two numbers when pairs of dots were presented.

RESULTS

The distribution of correct responses on the dot localization tasks is given in Table 1. The Mann-Whitney U statistic verified similar performance by the control and left hemisphere groups on the single and double dot tasks and both tasks combined (Table 2). In contrast, the right hemisphere group made significantly fewer correct responses than the control or left hemisphere groups on the single and double dot tasks and both tasks considered together. Furthermore, a significant percentage of the right hemisphere patients obtained lower scores than any of the patients in the control or left hemisphere groups. This defective performance was shown by 27% on the single dot task, 36% on the double dot task, and 45% on both tasks combined.

TABLE 1

DISTRIBUTIONS OF CORRECT RESPONSES

No. correct	*Control*	*Left*	*Right*
Single dots (nine trials)			
9	11	7	4
8	7	7	2
7	4	4	5
6	—	3	5
5	—	—	1
< 5	—	—	5
Mean	8.32	7.86	6.27
SD	0.78	1.06	2.12
Double dots (18 trials)			
17–18	1	—	1
15–16	3	4	3
13–14	10	8	2
11–12	5	6	1
9–10	2	1	3
7–8	1	2	4
5–6	—	—	5
< 5	—	—	3
Mean	12.77	12.52	9.05
SD	2.22	2.42	4.16
Both tasks (27 trials)			
25–26	1	2	1
23–24	3	3	3
21–22	13	6	2
19–20	2	7	0
17–18	2	2	3
15–16	—	—	—
13–14	1	1	3
11–12	—	—	4
< 11	—	—	6
Mean	21.07	20.38	15.32
SD	2.62	2.92	5.79

Five of the 22 patients with right hemisphere lesions had visual field defects and all performed poorly, three showing gross defects in localization and two making borderline scores of 14 correct responses. The mean score (10.8 correct responses) of these five patients was significantly lower than that (16.6 correct responses) of the 17 patients without field defects. An approximately equal number of errors (49 *vs* 47) was made by the patients with field defects in localizing dots to the left or right of the midline. In contrast, the mean score (19.1 correct responses) of the nine patients with visual field defects in the left hemisphere group was not significantly lower than that (21.3 correct responses) of the 12 patients without field defects in that group.

TABLE 2

MANN-WHITNEY U STATISTIC Z-SCORES FOR COMPARISONS OF GROUP PERFORMANCES

Comparison	Dot task		
	Single	*Double*	*Both*
Control *vs* left	1.34	0.33	1.36
Control *vs* right	3.54†	2.86*	3.09†
Left *vs* right	2.59*	2.81*	2.87*

* P < 0.005. † P < 0.001.

Aphasia did not appear to be a determinant of performance level. Within the left hemisphere group, the 12 aphasics obtained an overall mean of 19.8 which was not significantly different from the mean of 21.2 for the non-aphasics ($t = 1.15$, NS). Performance was not significantly related to age in any of the three groups. Since the majority of right hemisphere damaged patients were males, as opposed to nearly equal numbers of males and females in the other groups, the relationship between sex and defective performance was examined but found to be non-significant ($\chi^2 = 0.51$, NS). Fifty per cent of the males and 33% of the females performed defectively.

Radiographic techniques permitted specification of locus of lesion in only 15 of 22 patients with right hemisphere disease. Four patients with prefrontal lesions performed normally. Four of five (80%) of the patients with perirolandic lesions—that is, posterior frontal-anterior temporal or posterior frontal-anterior parietal lesions—were defective. Three of six (50%) of the patients with posterior parietal and/or occipital lesions were defective.

DISCUSSION

The dot localization task clearly discriminated between the two groups with unilateral brain disease, almost half of the patients with right hemisphere lesions performing below the level of the poorest patient in the left hemisphere group. In contrast, the performance of the latter group was not different from that of the control patients.

Thus our results confirm those of Warrington and Rabin (1970) in indicating that the right hemisphere plays a specifically important role in subserving visual dot localization. Since different groups of patients were investigated and, the distributions of the individual scores were not given in the Warrington-Rabin paper, it is not possible to make a precise comparison of the tasks employed in the two studies with respect to the degree to which they differentiated between patients with right and left hemisphere lesions. However, there are indications that the more demanding task utilized in the present study probably did separate the groups more sharply. As has been noted, the rather low mean error scores of the patients in the Warrington-Rabin study imply that a substantial proportion of them made perfect or near-perfect scores. In contrast, no patient in the present study made a perfect performance and only four percent made near-perfect performances (one to two errors), thus tending to enhance the opportunity for between-group differentiation. Moreover, in the present study, the double dot component of the task elicited a higher frequency of defective performance by the patients with right hemisphere disease than did the single dot component. Finally, the difference in the performance levels of the right and left hemisphere groups on their combined 'perceptual matching' task (dots, lines contours) was significant at the 0.05 level in the study of Warrington and Rabin (1970). In the present study, with a smaller number of cases, the between-groups difference in performance on the dot localization task was significant at the 0.005 level. In any case, it is clear that, when the level of a dot localization task was augmented by reducing stimulus exposure time and requiring the localization of two simultaneously present dots, a remarkably high proportion of patients with right hemisphere disease performed defectively.

There was a clear association between subnormal performance and the presence of visual field defect in the patients with right hemisphere disease. No such correlation was found for patients with left hemisphere lesions. This interaction between visual field defect and side of lesion as joint determinants of performance level has been found in a number of studies of visuo-perceptive functions in patients with unilateral brain disease (De Renzi and Spinnler, 1966; De Renzi *et al.*, 1971). The observation evidently contradicts that of Ratcliff and Davies-Jones (1972) who found no association between the presence of visual field defect and accuracy of localization, even in the visual field contralateral to the side of lesion.

Whether or not visual field defect will be related to performance level apparently depends upon the nature of the localization task. Field defects to not seem to be of importance when the task calls for a simple pointing response to the presentation of a single dot. On the other hand, when the task requires searching a field to identify a previously presented dot or dots, visual field defect interacts with side of lesion to produce impaired performance. It is not at all clear why there should be this variable influence of visual field defect on performance. A possibility that comes to mind is that the patient with a left field defect will not search the left half of space efficiently and consequently will make more errors. However, this possibility is negated by our finding that the patients with left field defect made about the same number of errors in localizing dots on the right as on the left. A study in which the Ratcliff and Davies-Jones procedure and a dot localization task of the type used in the present study are given to the same patients and in which pattern of performance on the two tasks is related to locus of lesion and the presence of visual field defect might clarify this question.

Both Warrington and Rabin (1970) and Ratcliff and Davies-Jones (1972) implicated the posterior parieto-occipital area as the site of lesions most closely associated with defective localization, although they differed on the question of whether there were lateral differences in this respect. The number of patients with cleary localizable single lesions in the present study was too small to permit a definite conclusion on this issue. Three of the six patients with lesions in the right posterior parietal area performed defectively, which is close to the overall proportion of failure (45%) in the right hemisphere group. However, the highest relative frequency of defective performance was shown by the five patients with posterior frontal-anterior parietal or posterior frontal-anterior temporal lesions. The majority of these patients showed contralateral motor or somatosensory impairment, but, as would be expected, none had visual field defects. Given the very small number of cases, this finding may simply reflect fluctuation in sampling. However, it does raise the question of whether lesions in this area may be more frequently associated with defective spatial localization than is usually assumed.

The finding that a substantial proportion of patients with right hemisphere lesions performed defectively suggests the potential value of a dot localization task such as this in the clinical assessment of patients with suspected brain disease. However, the tachistoscopic presentation of the stimuli employed in this study makes for a rather expensive and time-consuming procedure which is not likely to be adopted. Modifications of the procedure, which would eliminate the requirement of a tachistoscope and which would provide for a relatively short period of testing, deserve to be explored.

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