

Some determinants of visual neglect

JONATHAN LEICESTER, MURRAY SIDMAN, LAWRENCE T. STODDARD,
AND JAY P. MOHR

From the Massachusetts General Hospital, Boston, Mass., U.S.A.¹

Some patients with brain lesions do not respond normally to stimuli from the side opposite their lesions, and behave as though the stimuli were not present. This phenomenon is called neglect or inattention. A number of manifestations of neglect occur: neglect on double simultaneous stimulation (visual, auditory, tactile), neglect during reading, drawing, picture description, and the complex phenomena of neglect of the opposite side of space and neglect of the opposite half of the body. Each of these types of neglect involves particular neurological functions and differs in some way from the others.

The present paper will contribute to the understanding of a type of neglect which was originally observed during matching-to-sample tasks with visual choices. Not only did some patients neglect the choices on the side opposite their lesions, but these patients did not show their neglect on all tests. The neglect appeared when the patient, for some other reason—for example, aphasia—could not do the test correctly.

The study also brings some evidence to the problems of whether neglect can occur in the absence of a 'primary' sensory defect and whether neglect occurs after lesions of either hemisphere or only or mainly after lesions of the minor hemisphere.

METHODS

PATIENTS Eighteen patients with left hemisphere lesions and six with right hemisphere lesions were evaluated. Four patients with Korsakoff's psychosis and one case of presenile dementia served as a control group. Table I shows that many of the patients were stroke cases, others had tumours. Most of the patients with strokes were studied in the early weeks of their illnesses. The patients were right handed except for J.H.B., who was left handed. The patients' eye movements and visual fields were assessed by standard clinical methods. The visual fields are given in Table I. The eye movements were usually unremarkable.

¹From the Behavior Laboratory, Neurology Service, Joseph P. Kennedy, Jr. Memorial Laboratories, Massachusetts General Hospital. Reprint requests to Neurology Service, Massachusetts General Hospital, Boston, 02114, U.S.A. (Dr. Sidman).

Only two of the patients, H.E.D. and E.J., had gross neglect, obvious in their conduct on the ward. Slight neglect may have been overlooked; several of the patients had suggestive features on close inquiry. For instance, A.E.F.'s daughter, on direct questioning, felt that her mother was inattentive to those on her right when in a crowded room.

PROCEDURE The patients did the matching-to-sample tasks in a quiet, softly lit room. They sat before a panel of nine 2-in. × 2-in. translucent windows arranged in a 3 × 3 matrix. The whole matrix subtended about 18° of the patient's visual field. The patient could move his head and eyes freely, and could take as long as he wished to do each step of the procedure.

Stimuli were projected onto the windows from the rear. First the sample was presented; the patient then pressed the centre window to bring the choice stimuli onto the outer windows. The patient selected and pressed one of the choice windows. The choices then disappeared and if the patient had chosen correctly he was rewarded by chimes ringing and delivery of a nickel. After a short interval the sample for the next trial appeared. All choice stimuli were visual. The samples were visual (on the centre window), or auditory (over a speaker), or tactile (objects to handle or raised letters, words, numbers mounted on a cork board). The matching was either simultaneous (the sample remained while the choices were present), or delayed (the sample disappeared after the centre key press and the choices appeared from 0 to 40 seconds later). The procedure, including a record of the results, was automatic.

Each test consisted of a set of trials, usually 20, each of the same category—for example, single letters from an auditory sample. The materials used for the tasks included single letters, consonant trigrams—for example, 'pfx'—words, pictures, colours, colour names, digits, digit names, dots (to be counted and matched with digits), and ellipses (to be matched according to 'flatness'). There were either eight choices or six choices (with two blank choice windows) for each trial.

RESULTS

OCCURRENCE OF NEGLECT Patient J.S.C., a 63-year-old man, was studied after a stroke that caused right hemiparesis, aphasia, and transient right hemianopia. Figure 1 shows his neglect during the first 10 months.

TABLE I
EVALUATION OF PATIENTS FOR NEGLECT IN MATCHING-TO-SAMPLE

Patient	Diagnosis	Time of study	Visual field	Trials (no.)	L/L+R ratio		
					e.	c.	e.s.h.
R.D.	L. deep temporal glioma (necropsy)		Dense hemianopia	169	98	97	37
R.M.	LMCA embolus	4 wk	Hemianopia	237	92.5	75.5	34
M.M.	LMCA embolus	2 wk	Normal (campimetry 2/1000 R)	183	86.5	67	32
A.E.F.	LMCA embolus	6 d-4 wk	Transient defect (campimetry)	624	85	64	27
M.C.	LMCA embolus	2 wk	Hemianopia	413	78	74.5	30
M.McL.	LMCA embolus	2 wk	Transient defect	479	78	62	35
*J.S.C.	LMCA territory infarct	1 wk-18 mth	Transient defect	1,690	74	61	36
*V.C.C.	LMCA territory infarct	2 wk-10 mth	Transient defect	247	73	59.5	44
R.N.B.	Amnesic aphasia associated with mastoiditis	2 wk	Normal	243	71.5	57.5	42.5
R.J.M.	LMCA embolus	1-3 wk	Transient defect	418	69	57.5	41
*A.J.G.	LMCA embolus	4 wk-9 mth	Transient defect	1,518	68.5	57.5	42.5
*J.L.P.	LICA occlusion (arteriogram)	3 wk-12 mth	Dense hemianopia (campimetry)	8,879	59	57	39
J.H.B.	Bilateral ICA disease L>R (arteriogram)		Normal	313	58.5	53	46
*T.E.R.	LMCA embolus	1-11 wk	Normal	720	57	56.5	42
W.C.	Head injury. Aphasia L. P-T-O laceration (surgery)	5 yr	Dense hemianopia	1,249	55	50	50
R.W.	LMCA occlusion (arteriogram)	12 mth-4 yr	Normal	3,536	54.5	51	49
G.D.K.	L. temporal glioma (surgery)		Normal	347	52	52	44
J.M.C.	LPCA territory infarction (necropsy)	1 d-3 mth	Dense hemianopia (campimetry)	689	46	52	46.5
E.J.	RICA occlusion (arteriogram)	3 wk	Partial defect	122	2.5	18	88
M.D.B.	RPCA territory infarct	2-3 mth	Dense hemianopia (campimetry)	372	10	38	73
H.E.D.	RMCA embolus (arteriogram)	3-10 wk	Transient defect (campimetry)	879	13.5	33.5	66.5
M.A.C.	Meningioma, R. temporal craniotomy	3 wk post-op	Normal (campimetry 2/1000 R)	537	16	41.5	61
M.V.C.	RICA occlusion (arteriogram)	3 wk	No extinction DSS				
M.W.	R. occipital glioma (surgery)		Transient defect	370	23	41.5	61.5
E.J.R.	Korsakoff's syndrome		Dense hemianopia (campimetry)	347	30	40	61
R.M.H.	Korsakoff's syndrome			458	56	49	51
E.T.T.	Korsakoff's syndrome			426	56.5	51	49
M.T.F.	Korsakoff's syndrome			423	48	52	48
R.E.R.	Presenile dementia, cause unknown			152	42.5	49	51
				604	42	50	50

* Tests done after recovery from neglect are not included.

The diagrams in Fig. 1 represent the panel of choice windows. From left to right the four panels show the total number of times he selected each window (t.), the number of times he selected each window correctly (c.), the number of times he selected each window incorrectly (e.), and the number of times the correct choice that he should have pressed appeared on each window when he actually made errors (e.s.h.). His correct responses and error responses were concentrated on the left side, and, when he

made errors, the correct stimulus was usually on the right side. He neglected the right-hand choices. This neglect was measured by four indices derived from the parts of Fig. 1 that compared the performance on the three left windows with that on the three right windows by the ratio (left/left + right). For J.S.C. the indices were: total presses (t.) 65.5%; correct presses (c.) 61%; error presses (e.) 74%; and positions that should have been pressed on errors (e.s.h.) 36%. Indices (t.) and (e.) were derived

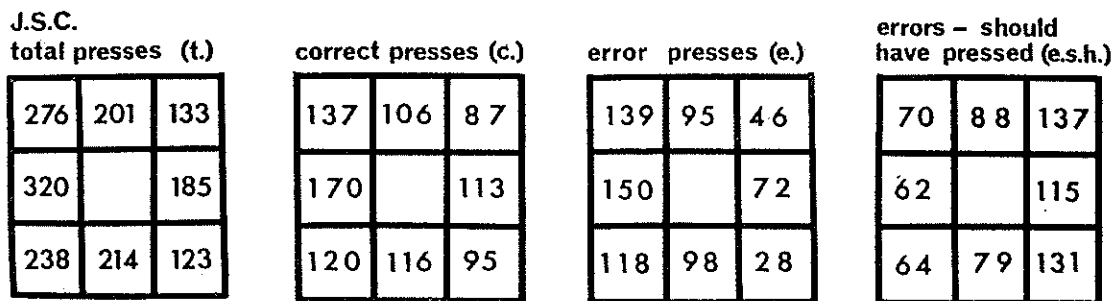


FIG. 1. Patient J.S.C., left middle cerebral territory infarction, showing neglect of the right-hand choices.

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directly from Fig. 1; indices (c.) and (e.s.h.) had slight corrections for the small difference in number of opportunities to be correct on the two sides.

Table I summarizes the results for all the patients. Of the 18 patients with left hemisphere disease 14 had neglect of the right, pressing predominantly on the left (e.), (c.). When they made errors, the correct stimulus was most frequently on the right (e.s.h.). The other four patients (W.C., R.W., G.D.K., J.M.C.) did not show neglect consistently on all indices; like the patients with Korsakoff's syndrome, they performed similarly on the two sides, and their indices approached 50%. The six patients with right hemisphere disease all had neglect of the left. Patients differed in the severity of neglect, but no patient totally neglected the contralateral choices.

NEGLECT AND ABILITY TO DO THE TASK Visual neglect did not prevent patients from doing tasks for which they had no other defect. Such tasks were done without error and no neglect showed. Neglect was not prominent during tasks for which the patient had only a slight defect; in these tasks there were many correct presses on each side. However, the occasional errors did reveal the neglect; when errors did occur the correct stimulus was usually on the neglected side, and the incorrect stimulus selected was usually on the favoured side. The neglect became conspicuous during tasks that the patient did poorly. We have not yet seen an exception to these rules, which will now be illustrated.

The relation between neglect, measured by total presses (t.), and ability to do the test is illustrated by Fig. 2, which shows four patients with left hemisphere and two with right hemisphere disease. The tests were divided into four groups on the basis of the patients' scores; tests done badly (<30% of responses correct), errorless tests (score 100%), and two intermediate categories. The neglect was not seen at all on the errorless tests; it appeared on the tests done fairly well and was even more apparent on the tests done very badly. The relation is further elucidated by Fig. 3, which deals with the correct presses (c.), error presses (e.), and correct choices that should have been pressed when errors were made (e.s.h.), for two cases. Even the occasional errors in tests done well reflect the neglect.

The existence of errorless tests, as the correct choices were equally distributed on the two sides, showed that neglect need not occur; that if the patient was sufficiently capable at the task he did it without trouble despite his neglect. The tests that were done well were different from patient to patient. They were determined not by the neglect but by the patient's deficit, and were not simply the 'easiest' tests. For instance, the cases with right hemisphere

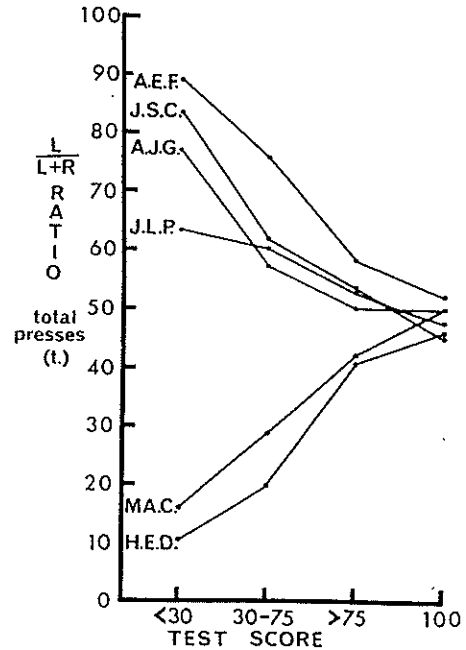


FIG. 2. Relation between neglect and ability to do test. Neglect assessed by total presses (t.). H.E.D. and M.A.C. have right hemisphere lesion, all others have left hemisphere lesion.

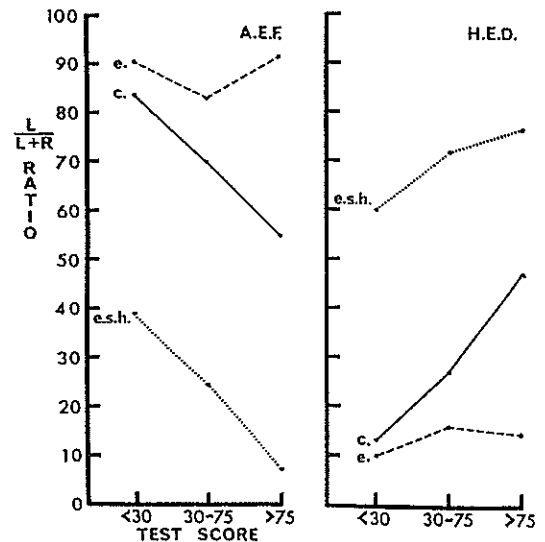


FIG. 3. Relation between neglect and ability to do test. Neglect assessed by correct presses (c.), error presses (e.), and positions of correct choices that should have been pressed on errors (e.s.h.). A.E.F., left middle cerebral artery embolus. H.E.D. right middle cerebral artery embolus.

lesions succeeded at one of the 'hardest' tests, a trigram test illustrated by the following trial: sample stimulus pkn; choice stimuli phn, pkn, xht, pkt, xkn, xhn, pht, xkt. The occasional errors in tests done well included some that occurred in trials which had the correct choice on an ipsilateral window; suggesting that a factor other than neglect contributed to the errors. The tests done badly were the tests that required abilities that were badly damaged in that patient—for example, language tests in aphasic patients.

Three specific experiments confirmed these findings:

Circle ellipse discrimination The task was to select a circle from a display of one circle and seven ellipses. The matrix was the same as in matching-to-sample, but the centre window was not used. On a given trial the ellipses were identical, but they varied from trial to trial among 10 steps of ellipse 'flatness'. The easiest trials had the 'flattest' ellipses with a vertical axis: horizontal axis ratio of 0.17; in the hardest trials with the 'roundest' ellipses the axis ratio was 0.95. All trials at any one ellipse size had the same wrong choice on all windows; only the position of the circle varied. In 80 trials the circle appeared once on each window for each step in ellipse size, and the steps were presented intermingled in a mixed sequence. The results with two patients are shown in Figure 4. The left graph shows their scores and the right graph their neglect (total presses) for each ellipse size. The relation between ability to do the test and neglect is apparent. On the easiest discrimination (0.17 ellipse) both patients

had errorless performances and no neglect; on the hardest discrimination (0.95 ellipse) they performed poorly and their underlying neglects were manifest.

Control patients, who had no neglect on matching-to-sample tasks, manifested no neglect on the circle-ellipse discrimination, even when their accuracy was low.

Different neglect with similar choice panels In these tests the choice matrix was identical for two different tasks, yet the patient showed no neglect during one task and obvious neglect during the other, demonstrating that the visual and spatial properties of the choice stimuli did not control the neglect.

Four examples are illustrated by Figure 5. Patients H.E.D. and M.D.B. (left half of Fig. 5) scored poorly in matching tactile letter samples to visual letter choices, and neglected the left side of the matrix during this task.¹ However, they accurately matched auditory letter-name samples to the same visual choices, and showed no neglect. Examples of the identical choice displays are shown above the graphs. Patients M.M. and A.J.G. (right half of Fig. 5) showed no neglect during correct matching of single letters from visual samples but neglected the right side during faulty matching of the same letters from auditory samples. Examples of the choice panels during these tasks are shown below the graphs. The change in modality of the sample *per se* could not have accounted for the

¹Patients with right hemisphere lesions frequently have trouble with this tactile task, with both the ipsilateral and the contralateral hand (personal observation).

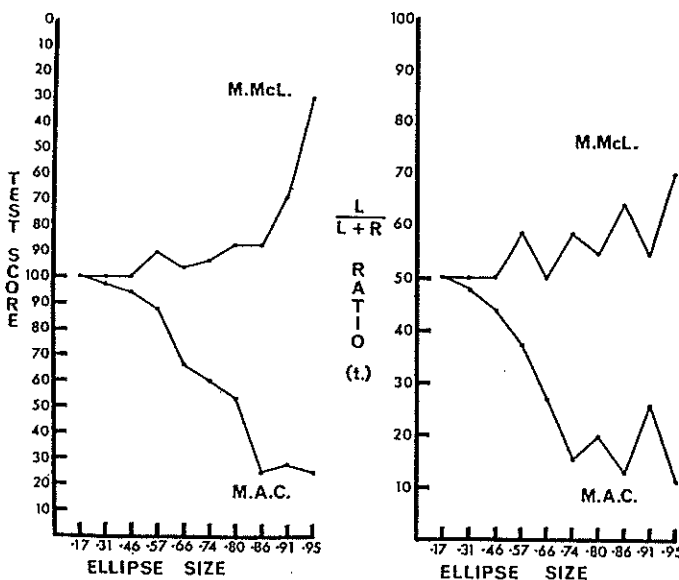


FIG. 4. Relation between neglect and ability to do test. Discriminating a circle from ellipses. Left side: Ability to do test at each ellipse size. Right side: Neglect at each ellipse size, assessed by total presses (t.). M.McL., left hemisphere lesion. M.A.C., right hemisphere lesion.

Ability to do test.
H.E.D. and M.A.C.
with left hemisphere

H.E.D.

Ability to do test.
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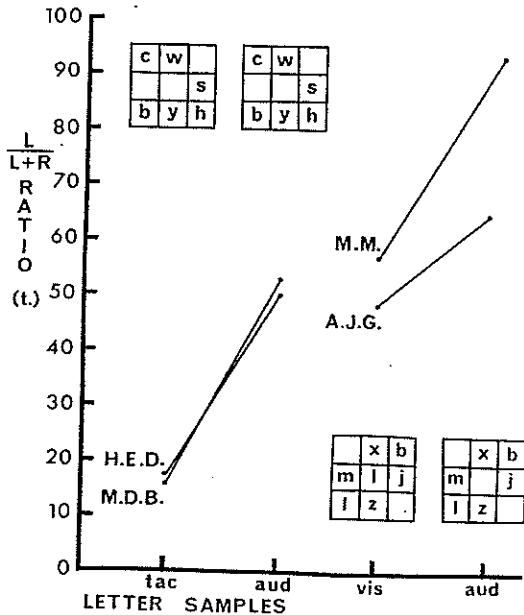


FIG. 5. Different neglect with similar choice panels in same subject. Four examples. Neglect assessed by total presses (t.). Neglect correlated with ability to do test, not with configuration of choice panel.

change in neglect, as was apparent on considering all the patient's tests.

Manipulation of neglect Figure 6A illustrates a trigram-matching task in which all the wrong choices are composed of the same three consonants as the sample. Figure 6B illustrates another trigram-matching task in which the wrong choices had different consonants. Some patients who made many errors in matching the similar trigrams (Fig. 6A) and had little trouble with the dissimilar trigrams (Fig. 6B) were given special tests with dissimilar trigrams (easy task) on the favoured side of the matrix and similar trigrams (difficult task) on the neglected side. Figure 7 presents the special-test

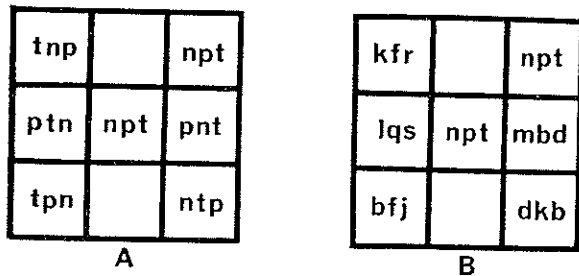


FIG. 6. Two types of trigram-matching tests.

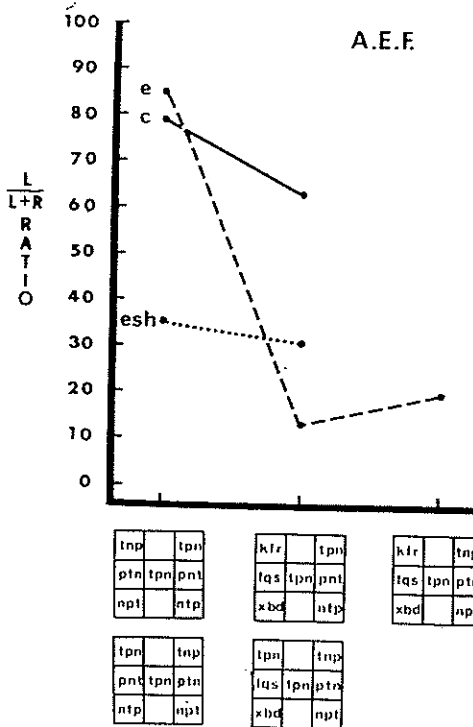


FIG. 7. Manipulation of neglect by specially constructed test (see text).

data of one of these patients. The tasks are illustrated by the window matrices along the abscissa. The patient had 20 trials with each of the five types of task illustrated, in a mixed sequence. The two matrices on the left exemplify an orthodox similar-trigram display with the correct choice on the right (upper matrix) and on the left (lower matrix), and show the patient's severe neglect of the right.

The two centre matrices exemplify tests in which dissimilar trigrams were available as wrong choices on the favoured left side, and similar trigrams on the normally neglected right side. Again, the correct window was sometimes on the right and sometimes on the left. On these tests the patient showed a dramatic reversal of one neglect parameter; when her favoured left side was presented with a task she performed well, her error responses (e.) were shifted into her normally neglected right side. Although it is not shown in Fig. 7, 87% of her responses on the right side came when there was no correct choice available on the left side.

The right-hand matrix exemplifies a special test like the two centre matrices, except that no correct choice was possible. Again, the patient's error

responses (e.) were shifted to the right side.

In summary a task that she performed well on the left side a task she performed poorly on the right side her responses were shifted to the right side. This manipulation of neglect is a function of the relation between r

OTHER FACTORS
Subjects have a wide range of samples and instances of neglect. Some have not yet been tested for specificity of neglect for particular parts of the body. Patients vary in the severity of neglect; some require separate tests for each side.

Hand used
Patients who neglect the right side will press the win button with the left hand.

Choice panel
The size of the choice panel can be changed in neglect tests.

Number of trials
The number of trials on each trial can be varied.

Visual field
Patients with abnormal visual fields can be tested with a window matrix (J.M.C.) with no neglect; a window matrix with neglect; a window matrix with neglect after stroke. Two windows on Bje and at the same time on the left side of the patient's cerebral cortex and transient pathogenesis of neglect in relation to the side of the brain.

Recovery
Neglect in or out of the laboratory.

1. Recovery of neglect rapidly regained. Thereafter, the patient showed no severe neglect as before, but performed poorly, further than neglect.

2. Recovery of neglect occurred, neglect tended to be neglected (J.S.C., J.L.) seen as early as possible.

A.E.F.

responses (e.) shifted into the usually neglected right side.

In summary: by presenting on her preferred side a task that she performed well and on her neglected side a task she performed poorly, the patient's error responses were shifted into her neglected side. This manipulation supported the importance of the relation between neglect and ability to do the task.

OTHER FACTORS AND NEGLECT *Category of choices* Subjects have shown neglect with all the categories of samples and choices we have used. Unequivocal instances of modality or material specific neglect have not yet been documented. Such apparent specificity was always more appropriately accounted for by the patient's accuracy for the tasks. The patients varied in the tests and modalities for which they were most deficient; the analysis of these deficits requires separate treatment.

Hand used Several patients, who were able to press the windows with either hand, had the same neglect whichever hand they used.

Choice panel size Reducing the choice panel to a card the size of the centre window produced no change in neglect in cases R.J.M. and M.M.

Number of choices Some subjects were given tests in which only two windows contained choices on each trial; they showed neglect with these tests.

Visual field defects (Table I) Although visual field abnormalities were frequent they did not correlate precisely with neglect. Two patients (W.C., J.M.C.) with severe and persistent hemianopia had no neglect; and J.M.C. was studied soon after his stroke. Two patients (M.M., M.A.C.) had normal fields on Bjerrum screen testing with 2 mm discs, and at the same time showed marked neglect. Many of the patients with vascular disease of the middle cerebral or internal carotid arteries had a partial and transient disturbance of their visual fields. The pathogenesis of this disturbance was uncertain, and its relation, if any, to neglect was unclear.

Recovery from neglect Patients recovered from neglect in one or both of two ways:

1. Recovery from task deficit. Many patients rapidly regained their ability to do some tasks. Thereafter, they did those tasks without error and showed no neglect, although neglect remained as severe as before on other tasks which they still did poorly, further suggesting that some factor other than neglect was contributing to the errors.

2. Recovery from basic neglect. When this occurred, neglect was no longer seen even with tasks the patient still could not do well. In stroke patients neglect tended to diminish and disappear (V.C.C., J.S.C., J.L.P., T.E.R., H.E.D.). This recovery was seen as early as one month and as late as one year

after the stroke; it was sometimes associated with a period of overcompensation. In all these patients some tests were still done poorly after the neglect had recovered. This proved that a defect other than neglect had contributed to the errors on these tests.

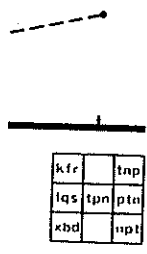
DISCUSSION

IMPLICATION FOR OTHER TYPES OF NEGLECT The term 'neglect of the opposite side of space' commonly refers to general symptoms such as neglecting people, furnishings, utensils, etc., and to special categories concerned with reading, picture description, and drawing. The type of neglect we have observed here is one such special category. But it should be recognized that the patient must be capable in two ways if he is to cope with the 'space' around him. First, he must make correct spatial responses to the position of each object around him—for example, point to it, avoid it, judge its distance from him, etc. Second, he must make appropriate non-spatial responses—for example, name each object, use it appropriately, match it to a sample, etc.

In many of the cases described here, the contributions of these two capabilities to the manifestation of neglect were separated. Neglect was produced by an inability to perform non-spatial aspects of the tasks, in this instance matching the choices to samples. Neglect appeared during faulty performances and disappeared during errorless performances, even while the choice display, and hence the spatial aspects, remained the same. Also, neglect was not affected by greatly reducing the size of the display panel, although the spatial aspects were thereby altered.

The patients did have a basic tendency to neglect, the severity of which was measured by the index of error presses (e.). But, for the neglect to be manifest, there had to be a deficit in the non-spatial aspects of the task being attempted. These considerations suggest five theoretical forms in which neglect of the opposite side of space could occur, the first three of which require deficits other than the neglect itself:

First, neglect related to the patient's inability to make appropriate non-spatial responses (naming, using, matching, etc.) to the objects concerned. This category of neglect has been demonstrated here. The category is complex, for there may be several reasons for failure to make these responses. A defect of language accounted for much of the defective performance of the patients with left hemisphere disease, most of whom had severe aphasia. Defective memory could cause failure on delayed matching tests, but was not prominent in the patients studied here. Setting tests that were beyond the patients' premorbid capacities would have led to errors.



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However, all the tests used in this study can be easily done by normal adults, except perhaps the most difficult (0.95) trials of the circle-ellipse discrimination.

Second, neglect related to the patient's inability to respond appropriately to the spatial properties of objects themselves (their shapes). It was notable that the patients with right hemisphere lesions failed tests in which this requirement seemed particularly exacting. They had difficulty with the similar-trigram test (Fig. 6A) and other 'form reversal' tests,¹ with the ellipse matching tests, and matching letters from tactile samples. This pattern of deficits may have resulted from poor responses to the spatial properties of the objects themselves (their shapes), although this was not proven.

Third, neglect related to an inability to handle the spatial aspects of the task (pointing to, avoiding, etc.); a defect related to the positions of objects in relation to each other and to the subject. Several writers have favoured views similar to this (McFie, Piercy, and Zangwill, 1950; Ettlinger, Warrington, and Zangwill, 1957; McFie and Zangwill, 1960; Hecaen, 1962). We propose, however, that the neglect is not itself the spatial defect. Rather, there is an underlying spatial defect, separable from the neglect, that allows the neglect to appear by causing a deficient performance of the task.

Fourth, there may be tasks, unlike those studied here, in which an otherwise normal ability to do them does not prevent neglect from appearing. This type of neglect should depend only on the basic neglect itself, measured by the index of error presses (e.), and might appear in patients like those studied here.

Fifth, there may be patients, completely different from those studied here, in whom neglect appears in any test that involves spatially distinct stimuli, even if there is no deficit other than the neglect itself.

Neglect of the opposite side of the body and extinction of double simultaneous stimulation may seem rather removed from the neglect studied here, yet a similar approach to these problems might have value. The difficulty of defining and measuring the various tasks that make up complex functions such as 'awareness of one's body' is a bar to progress.

NEGLECT AND SIDE OF LESION Neglect of the opposite side of the body and some forms of neglect of the opposite side of space have been attributed to disease of the non-dominant hemisphere. The reality and significance of this localization have been controversial matters (Brain, 1941; Paterson and

Zangwill, 1944; McFie *et al.*, 1950; Denny-Brown, Meyer, and Horenstein, 1952; McFie and Zangwill, 1960; Hecaen, 1962; Denny-Brown, 1962). In the present paper neglect was seen with lesions of either hemisphere; nevertheless, on certain individual tasks neglect occurred predominantly or entirely after lesions of a particular hemisphere. A good example is the matching of single letters from an auditory sample. The task was done correctly and without neglect by all the patients with right hemisphere lesions, whereas some of the patients with left hemisphere lesions failed the task and neglect appeared (Fig. 5). In this task neglect occurs only as neglect of the right and due only to left hemisphere disease, provided the left hemisphere is dominant.

Perhaps the same mechanism underlies the predominance of neglect of the left side of the body and the left side of space, suggesting that the minor hemisphere has special 'body image' and 'spatial' functions which, when defective, allow these neglects to appear. The types of neglect of the opposite half of space that are predominantly due to right hemisphere disease may be of the second and third types in our classification.

NEGLECT AND 'PRIMARY SENSORY' DEFECT The question of whether neglect always reflects a primary sensory defect is a controversial one (Kennard, 1939; Bender and Furlow, 1945; Holmes, 1945; Wortis, Bender, and Teuber, 1948; Allen, 1948; Critchley, 1949; Denny-Brown *et al.*, 1952; Welch and Stuteville, 1958; Birch, Belmont, and Karp, 1964; King, 1967). The new observation we can make is that a primary sensory defect is not sufficient to cause neglect to appear. This follows from the finding that the patients showed no neglect on some tasks. A defect in performing the task was required for neglect to appear, even if a primary sensory defect did exist.

There is still the question of whether the underlying tendency to neglect is due to a sensory defect. Two of our patients (M.M., M.A.C.) had normal visual fields, so one would have to invoke more subtle abnormalities of sensation to sustain the argument. Such abnormalities—for example, in flicker fusion, fading time, stroboscope, stereoscope and tachistoscope tests—are known to be common (Bender and Furlow, 1945; Wortis *et al.*, 1948; Bender and Teuber, 1947-48; Bay, 1953), although their functional significance is not clear (Ettlinger *et al.*, 1957). Nor is it clear in what sense they are 'primary' sensory defects. Although more detailed study may reveal correlations to exist, the evidence available at present suggests that visual neglect may be separate from the function of the optic radiation and striate cortex.

¹Tests where the choices on each trial were the same group of stimuli arranged in different orders. Geometrical figures (e.g., sample stimulus $\square \triangle$) and coloured bars have been used in addition to trigrams.

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SUMMARY

A matching-to-sample technique proved to be a sensitive method of detecting and assessing visual neglect. Fourteen of 18 left hemisphere cases and all six right hemisphere cases showed contralateral neglect. The neglect was qualitatively the same in all patients, but varied in severity from case to case. The study did not show whether neglect due to left hemisphere disease was quantitatively the same as neglect due to right hemisphere disease.

The patients did not show their neglect on every test, but only on those which, for some other reason, they could not do correctly. The reasons for failure were the consequences of their lesions, as the study used simple tests that normal adults do easily. The patients did other tests without any errors and without showing neglect. One consequence of this was that neglect in particular tests was confined mainly or entirely to either the left hemisphere or the right hemisphere cases. For instance, during matching of single letters from auditory samples, neglect only of the right occurred and only in cases of left hemisphere disease. The patients with lesions of the right hemisphere were able to do the test correctly and did not show neglect. Perhaps a similar mechanism causes some other forms of neglect to occur mainly as neglect of the left due to right hemisphere disease.

Neglect did not have any simple relation to visual field defects by conventional testing. Neglect was most marked in the first weeks after a stroke, and tended to recede gradually during the following months.

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REFERENCES

- Allen, I. M. (1948). Unilateral visual inattention. *N.Z. Med. J.*, 47, 603-517.
- Bay, E. (1953). Disturbances of visual perception and their examination. *Brain*, 76, 515-550.
- Bender, M. B., and Furlow, L. T. (1945). Phenomenon of visual extinction in homonymous fields and psychologic principles involved. *Arch. Neurol. Psychiat. (Chic.)*, 53, 29-33.
- , and Teuber, H.-L. (1947-48). Spatial organization of visual perception following injury to the brain. *Ibid.*, 58, 721-739 and 59, 39-62.
- Birch, H. G., Belmont, L., and Karp, E. (1964). The relation of single stimulus threshold to extinction in double simultaneous stimulation. *Cortex*, 1, 19-39.
- Brain, W. R. (1941). Visual disorientation with special reference to lesions of the right cerebral hemisphere. *Brain*, 64, 244-272.
- Critchley, M. (1949). The phenomenon of tactile inattention with special reference to parietal lesions. *Ibid.*, 72, 538-561.
- Denny-Brown, D., Meyer, J. S., and Horenstein, S. (1952). The significance of perceptual rivalry resulting from parietal lesion. *Ibid.*, 75, 433-471.
- (1962). In *Interhemispheric Relations and Cerebral Dominance*, edited by V. B. Mountcastle pp. 244-252. Johns Hopkins Press: Baltimore, Md.
- Ettlinger, G., Warrington, E., and Zangwill, O. L. (1957). A further study of visual-spatial agnosia. *Brain*, 80, 335-361.
- Hecaen, H. (1952). Clinical symptomatology in right and left hemisphere lesions, pp. 215-243, in *Interhemispheric Relations and Cerebral Dominance*, edited by V. B. Mountcastle. Johns Hopkins Press: Baltimore, Md.
- Holmes, G. (1945). The organization of the visual cortex in man. *Proc. roy. Soc. B*, 132, 348-361.
- Kennard, M. A. (1939). Alterations in response to visual stimuli following lesions of frontal lobe in monkeys. *Arch. Neurol. Psychiat. (Chic.)*, 41, 1153-1165.
- King, E. (1967). The nature of visual field defects. *Brain*, 90, 647-668.
- McFie, J., Piercy, M. F., and Zangwill, O. L. (1950). Visual-spatial agnosia associated with lesions of the right cerebral hemisphere. *Ibid.*, 73, 167-190.
- , and Zangwill, O. L. (1960). Visual-constructive disabilities associated with lesions of the left cerebral hemisphere. *Ibid.*, 83, 243-260.
- Paterson, A., and Zangwill, O. L. (1944). Disorders of visual space perception associated with lesions of the right cerebral hemisphere. *Ibid.*, 67, 331-358.
- Welch, K., and Stuteville, P. (1958). Experimental production of unilateral neglect in monkeys. *Ibid.*, 81, 341-347.
- Wortis, S. B., Bender, M. B., and Teuber, H.-L. (1948). The significance of the phenomenon of extinction. *J. nerv. ment. Dis.*, 107, 382-387.

Denny-Brown, and Zangwill, (1962). In the lesions of either individual tasks : entirely after a good example on an auditory ly and without ght hemisphere ients with left und neglect ap- occurs only as left hemisphere e is dominant. erlies the pre- of the body and hat the minor ' and 'spatial' v these neglects e opposite half to right hemi- and third types

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her the under- sensory defect.) had normal invoke more o sustain the example, in scope, stereo- known to be Wortis *et al.*, ; Bay, 1953), e is not clear in what sense lthough more s to exist, the ts that visual nction of the