Article abstract—Unilateral visual neglect is a common symptom or sign in patients with lesions of the nondominant hemisphere. Several techniques have been used to demonstrate visual neglect. One such technique—asking a patient to bisect a horizontal line and expecting an estimate of center away from the side neglected—has been used for over 70 years but has not been statistically evaluated. We conducted a formal evaulation of this method and found that under special conditions, line-bisection performance can discriminate between patients with right-hemisphere lesions and patients with diffuse lesions, patients with left-hemisphere lesions, and hospital controls. When used to investigate visual neglect in an individual patient, the line-bisection test should be given in conjunction with other complementary procedures such as symmetric drawings and the Memory-for-Designs Test.

NEUROLOGY 30: 509-517, **May 1980**

Line bisection and unilateral visual neglect in patients with neurologic impairment

T. Schenkenberg, Ph.D., D. C. Bradford, Ph.D., and E. T. Ajax, M.D.

Unilateral visual neglect—the tendency of patients with cerebral damage or disease restricted to one hemisphere to neglect or ignore visual stimuli that appear contralateral to the affected hemisphere—has been known to neurologists for over a century.[1-3] A number of extensive reviews have been presented.[1,4,5]

Brain[6] was the first to study this phenomenon systematically. He concluded that visual neglect was usually seen after damage to the right (nonspeech-dominant) hemisphere, and was thus encountered as left visual neglect. He indicated that the symptom was not due to visual-field or oculomotor abnormalities.

Some disagreement with these conclusions was voiced by other investigators,[7,8] who indicated that lesions in either hemisphere could cause neglect, that visual-sensory defects were essential to manifestation of visual neglect, and that patients with left-hemisphere disease might have visual neglect but cannot be adequately tested because of accompanying aphasia.

Although many aspects of this debate remain open to discussion, recent reports support the following concepts: (1) Visual neglect is encountered far more often with lesions of the nondominant hemisphere.[9] (2) The correlation between visual-sensory defects and neglect is high but imperfect. A substantial percentage of patients with neglect also have field defects; the converse is not true.[10] (3) The correlation between oculomotor defects and neglect is poor. Oculomotor defects do not cause neglect, although they may amplify the problem in subtle ways.[11] (4) In all likelihood, aphasia does not mask neglect in patients with lesions of the left hemisphere.[12]

Several strategies have been used to study visual neglect, and some have become standard in clinical practice. For example, a patient is often asked to draw a series of symmetric items, with the expectation that patients with left neglect will produce drawings that are devoid of detail on the left and may be crowded to the right side of the page.

Another method of testing for visual neglect is to ask the patient to bisect a horizontal line. The expectation is that the patient will incorrectly estimate the center of the line to the right of true center, neglecting the left end of the line.[1,13-15] Some investigators have reported data for individual patients on a line-bisection task,[16] but this technique has not been systematically tested. It was the purpose of this study to do so. We also hoped to investigate the efficacy of the traditional

From the Veterans Administration Medical Center and the Department of Neurology, University of Utah College of Medicine (Drs. Schenkenberg and Ajax), and the University of Utah (Dr. Bradford), Salt Lake City, UT.

Accepted for publication August 14, 1979.

Address correspondence and reprint requests to Dr. Schenkenberg, Neurology Service, Veterans Administration Medical Center, Salt Lake City, UT 84148.

Table 1: Individual Subject Data

(See Column Key Below)

Right Hemisphere Damage (RD)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
R-01	18	X		RD	3	L-2	32	3 da	4	1	2	--	-		48.8	17.9	-18.3	R cerebral infarction	X	X
R-02	27	X		RD	3	L-2	28	4 mo	2	0	0	-			48.0	60.8	10.3	R hemisphere contusion	X	X
R-03	27	X	X	RD	2	L-1	22	5 yr	0	0	0	-4.7	-6.6	-8.7	3.0	-.1	6.4	R hemisphere contusion	--	
R-04	43	X	--	RD	1	L-1	25	2 wk	4	2	0				48.1	41.0	21.9	R cerebral infarction		-
R-05	47	X		RD	2	L-2		2 mo	1	0	5	-			31.4	-4 9	-11.7	R parieto-occipital mass lesion	-	--
R-06	49	X	X	RD	2	L-2		2 da	0	0	0	-2.7	1.7	1.6	2.6	8.9	8.0	R cerebral infarction	X	X
R-07	50	X	-	RD	3	L-2	29	2 wk	2	2	2	-			11.8	8.1	-2.0	R cerebral infarction	X	
R-08	52	X		RD	1	L-1	19	1.5 mo	3	1	1	-			9.0	14.7	-2.4	R cerebral infarction	-	-
R-09	53	X	X	RD	1	L-1	32	3 mo	0	0	1	11.7	1.8	-6.4	12.2	2.6	1.7	R parieto-occipital glioblastoma	X	
R-10	55	X		RD	3	L-3	31	10 mo	5	0	0	-	-		-5.6	-7.8	-9.1	R cerebral infarction	X	X
R-11	61	X	—	RD	1	L-1	11	1 mo	0	0	0	-			2.1	-2.3	3.6	Multiple R cerebral infarctions	X	-
R-12	61	X		RD	3	L-3		11 da	6	3	1				12.0	9.0	-11.9	R cerebral infarction	X	—
R-13	62	X	X	RD	3	L-3	45	2 da	11	13	0	64.7	74.3	74.3	80.4	76.9	79.7	R cerebral infarction	X	X
R-14	63	X	X	RD	2	L-2	27	--	10	4	1	-5.5	-19.3	-25.9	5.2	-4.1	-3.1	R frontal & parietal mass lesions	X	—
R-15	63	X		DD	1	-	21	5 mo	0	0	0				16.8	11.3	5.9	R cerebral infarction	X	X
R-16	64	X	—	LD	1		29	6 mo	0	0	0				4.6	7.7	6.7	R cerebral infarction	X	--
R-17	65	X	--	RD	3	L-3	19	2 wk	2	0	0				31.7	20.6	-7.9	R cerebral infarction	X	X
R-18	70	X	--	RD	1	L-1	40	14 yr	0	1	0	-			3.5	5.1	1.9	R cerebral infarction	X	--
R-19	79	X	X	RD	3	L-1	47	2 wk	4	1	2	17.8	15.4	11.2	19.4	11.4	-10.7	R cerebral infarction	—	—
R-20	80	X	X	RD	3	L-1	18	2 da	1	0	1	-11.1	1.8	10.9	-9.6	8.0	-12.2	R cerebral infarction	X	-

Left Hemisphere Damage (LD)

L-01	40	X	X	DD	1	-	5	5 yr	0	0	0	9.3	8.6	8.6	11.6	9.8	10.9	Multiple L cerebral infarctions	--	--
L-02	43		X	LD	3	-	39	4 mo	0	0	1	-19.1	5.6	7.3		-	-	L cerebral infarction	X	X
L-03	43	-	X	LD	1	—	7	2.5 yr	0	0	0	3.6	-.8	.4	--	-	-	L cerebral infarction	X	-
L-04	47	-	X	LD	1	--	26	5 da	0	0	0	.8	-4.2	-2.2	-	--	-	L cerebral infarction	—	--
L-05	48	X	X	HC	1	—	15	4.5 mo	0	0	0	2.3	-.1	-1.3	11.8	1.4	-6.8	L cerebral infarction	X	-
L-06	49	—	X	LD	2		17	6 mo	0	0	0	-1.8	3.4	1.0		-		L cerebral infarction	X	—
L-07	50	—	X	DD	3		10	5 yr	0	0	0	-7.7	-8.6	-2.3		--	-	L cerebral infarction	X	
L-08	50	X	X	LD	3	-	41	1.5 mo	0	0	2	19.9	-14.4	-38.2	54.7	-22.1	-66.0	L cerebral infarction	X	-
L-09	51		X	LD	1	--	17	3 mo	0	0	0	-7.3	-1.4	1.6			-	L cerebral infarction	X	-
L-10	55	X	X	HC	1	--	15	11da	0	0	0	1.8	-2.7	-1.0	-.2	-1.5	-3.5	L cerebral infarction	—	X
L-11	55	X	X	HC	3		2	4 da	0	0	0	-1.4	-.6	-1.7	2.8	.9	1.7	L cerebral infarction	X	--
L-12	55	X	X	LD	2	--	26	5 yr	0	0	0	-9.6	-28.4	-28.3	4.8	-9.4	-15.8	Multiple L cerebral infarctions	X	--
L-13	57	X	X	HC	1	-	14	2 mo	0	0	0	-7.2	-3.5	.7	-1.3	-1.9	1.8	L parietal mass lesion	-	--
L-14	59	X	X	HC	1	--	19	5 mo	0	0	0	-4.8	-3.0	-6.6	5.5	3.8	2.8	L fronto-temporal astrocytoma	—	
L-15	61		X	RD	1	L-1	29	--	0	0	0	.3	-4.9	-5.5	--	-	-	L fronto-temporal mass lesion	X	--
L-16	66	—	X	LD	3	—	34	2.5 mo	0	0	0	-11.5	-5.6	-26.5				L cerebral infarction	X	X
L-17	68	X	X	LD	1		27	8 mo	1	0	1	-5.5	-3.1	3.2	-6.2	-.5	7.2	L parietal cerebral infarction	-	X
L-18	72	--	X	LD	3	-	24	2 mo	0	0	0	3.3	-1.6	.2	-	—	—	L cerebral infarction	X	X
L-19	74	--	X	LD	3	-	34	2.5 mo	0	0	0	1.1	-5.3	-6.0		—		L cerebral infarction	X	—
L-20	80	-	X	LD	1	—	29	2.5 yr	0	0	0	30.4	-48.2	-75.1	-	—	-	L cerebral infarction	X	-

Diffuse Cerebral Damage (DD)

D-01	19	X	X	DD	1	--	15	—	0	0	0	-4.3	-2.5	-.6	6.2	.6	13.8	Post-traumatic cerebral edema	-	—
D-02	33	X	X	HC	3	-	1	-	0	0	0	-1.6	2.5	-.9	.5	5.0	8.9	Multiple sclerosis	--	--
D-03	35	X	X	DD	2	-	29		0	0	0	15.7	-9.3	-26.6	45.0	13.4	-37.8	Cerebral atrophy	—	—
D-04	40	X	X	DD	3	—	-	—	0	1	0	.7	-1.6	-4.2	12.7	7.7	6.2	Multiple sclerosis	-	--

D-05	41	X	X	DD	2	—	13	—	0	0	0	-5.5	-2.3	4.9	-13.9	-2.2	1.7	Huntington's chorea	—	—
D-06	41	X	X	RD	1	L-1	31	--	0	1	0	7.6	-5.7	-1.9	10.7	-.7	-9.4	Huntington's chorea	—	—
D-07	50	X	X	LD	1	—	16	—	0	0	0	1.0	-1.5	3.1	5.4	11.4	6.4	Pre-senile dementia	—	—
D-08	50	—	X	DD	2	—	32	—	0	0	0	6.2	-2.3	3.7	—	—	—	Multiple sclerosis	—	—
D-09	53	X	X	HC	2	—	14	—	0	0	0	13.8	-4.1	-10.4	10.8	5.3	-7.7	Multiple sclerosis	—	—
D-10	53	X	X	RD	1	L-1	—	—	1	0	1	11.1	-23.0	-2.5	29.4	18.5	7.6	Multiple sclerosis	—	—
D-11	54	X	X	DD	3	--	33	—	0	1	0	-6.4	-7.8	-5.8	-3.1	-3.3	-5.3	Idiopathic Parkinson disease	—	—
D-12	55	X	X	DD	1	—	21	—	0	0	0	8.9	-3.3	7.0	14.4	7.5	13.6	Idiopathic Parkinson disease	—	—
D-13	56	X	X	DD	1	—	12	—	0	0	0	2.7	1.4	-5.8	8.9	6.1	6.2	Cerebral atrophy	—	—
D-14	65	X	X	DD	2	—	—	—	1	0	1	10.4	-1.7	-1.1	-2.5	-4.4	-7.9	Cerebral atrophy	—	—
D-15	67	X	X	DD	2	—	31	—	0	0	0	-3.8	-.7	8.3	-1.4	-2.5	.9	Cerebral atrophy	—	—
D-16	68	X	X	DD	3	—	32	—	0	0	1	4.2	2.1	2.2	.2	2.5	-3.4	Senile cerebral atrophy	—	—
D-17	76	X	—	DD	2	—	35	—	0	0	0	—	-	--	-4.5	-8.8	-15.8	Senile cerebral atrophy	—	—
D-18	76	X	X	DD	2	—	—	--	0	0	0	1.5	-1.3	-3.9	2.1	6.5	5.2	Senile cerebral atrophy	—	—
D-19	80	X	X	DD	1	—	15	—	0	0	0	3.0	-3.8	-1.9	.3	2.8	.6	Senile cerebral atrophy	—	—
D-20	85	X	X	HC	2	—	14	—	0	0	0	-.8	.0	1.5	5.9	6.4	3.1	Idiopathic Parkinson disease	—	—

Hospital Control Group (HC)

C-01	20	X	X	HC	3	—	3	—	0	0	0	-9.7	-5.3	-1.4	-3.0	5.0	4.8	Hysterical conversion reaction	—	—
C-02	25	X	X	HC	3	—	8	-	0	0	0	-7.3	-14.8	-13.1	-4.8	-4.1	-9.4	Arthritis and GI hemorrhage	—	—
C-03	39	X	X	HC	3	—	11	—	0	0	0	-7.9	-4.4	-1.3	-6.1	.2	11.8	History of myocardial infarcts	—	—
C-04	39	X	X	HC	1	—	13	—	0	0	0	-3.3	-2.8	-4.4	.5	1.0	.6	Hysterical conversion reaction	—	—
C-05	40	X	X	HC	2	—	2	—	0	0	0	-.2	-.7	-.3	3.5	4.0	2.1	Chronic obstructive pulmonary disease	—	—
C-06	42	X	X	HC	3	—	7	—	0	0	0	.1	-2.5	1.6	-4.3	-1.8	4.3	Leukemia	—	—
C-07	44	X	X	HC	3	—	1	—	0	0	0	-8.0	-9.3	-6.1	-5.0	-2.0	-1.2	Chest pain, hypertension	—	—
C-08	45	X	X	HC	2	—	6	—	0	0	0	7.1	5.9	-.9	13.9	9.6	4.4	Hypertension	—	—
C-09	45	X	X	DD	1	--	25	--	0	0	0	-2.2	-5.7	-8.2	1.5	3.3	-1.2	Chronic obstructive pulmonary disease	—	—
C-10	47	X	X	HC	2	—	17	—	0	0	0	-14.2	-10.0	-.8	-7.7	-10.3	-3.1	Chest pain, GI infection	—	—
C-11	48	X	X	HC	3	—	1	—	0	0	0	-3.1	-2.5	-.9	-2.4	-1.9	-.8	GI pain	—	—
C-12	52	X	X	HC	2	—	6	—	0	0	0	-7.0	1.2	6.6	-1.6	5.0	15.9	Otitis media	—	—
C-13	55	X	X	DD	1	-	17	—	0	0	0	-4.6	-3.0	13.4	-9.3	3.7	-.1	Cirrhosis	—	—
C-14	55	X	X	HC	3	--	3	--	0	0	0	4.0	.4	-2.1	.9	.4	-.7	Cancer of the thyroid	—	—
C-15	56	X	X	HC	1	—	12	—	0	0	0	-6.2	-5.0	-2.0	-3.0	-3.6	-.5	Ulcerative proctitis	—	—
C-16	58	X	X	HC	3	-	17	-	0	0	0	-4.5	-4.5	2.1	2.8	.8	3.6	Heart disease	—	—
C-17	62	X	X	HC	1	—	[illegible]	—	0	0	0	4.6	3.0	-2.8	6.7	2.9	-.2	Duodenal peptic ulcer	—	—
C-18	66	X	X	HC	2	--	[illegible]	—	0	1	0	-8.5	-2.9	1.1	.7	3.9	8.2	Heart disease	—	—
C-19	68	X	X	DD	1	—	22	—	0	0	0	-3.2	-4.0	1.0	-.9	1.7	10.1	GI pain	—	—
C-20	79	X	X	HC	1	--	20	--	0	0	0	-4.2	-4.5	-.2	.6	4.2	2.8	Chronic obstructive pulmonary disease	—	—

COLUMN IDENTIFICATION:

1. Subject number
2. Age
3. Right hand used
4. Left hand used
5. Blind diagnosis from drawings
6. Confidence of diagnosis[a]
7. Side neglected — degree of neglect[b]
8. Memory-for-Designs Test score[c]
9. Time between onset of disease and neuropsychological testing
10. No. of left lines totally neglected
11. No. of center lines totally neglected
12. No. of right lines totally neglected
13. Percent Deviation of left lines with left hand. (Percent Deviation = $\frac{\text{measured left half} - \text{true half}}{\text{true half}} \times 100$)
14. Percent Deviation of center lines with left hand
15. Percent Deviation of right lines with left hand
16. Percent Deviation of left lines with right hand
17. Percent Deviation of center lines with right hand
18. Percent Deviation of right lines with right hand
19. Hospital diagnosis
20. Hemiparesis (or weakness)
21. Visual field defect

[a]Confidence of diagnosis was rated 1 (little or no confidence), 2 (moderate confidence), or 3 (great confidence.
[b]Severity of neglect was rated 1 (little neglect), 2 (moderate neglect), or 3 (severe neglect).
[c]Total number of errors according to the rating system used by Grundvig. 17

drawing tasks involving symmetric items and to examine the frequency of visual neglect in patients with lateralized or diffuse damage.

Methods. *Subjects.* Four groups of 20 right-handed patients were examined: (1) patients with right-hemisphere damage (RD), (2) patients with left-hemisphere damage (LD), (3) patients with diffuse cerebral damage (DD), and (4) general medical patients with no evidence of cerebral disease, a hospital control (HC) group. These patients were gathered from the Salt Lake City Veterans Administration Medical Center and the University of Utah Medical Center in Salt Lake City. Selection began with an initial referral from the medical staff, who had been apprised of the general nature of the experimental groups, but no attempt was made to recruit subjects with visual neglect. Patients were excluded if the diagnosis was inconclusive or if general health problems precluded testing. Special efforts were made to verify each diagnosis and to specify the nature and extent of the neurologic deficits. Individual patients received a neurologic examination and special procedures such as electroencephalogram (EEG), isotope brain scan, computerized tomography (CT), skull x-rays, and arteriograms as indicated. Visual field defects were investigated by confrontation and, when appropriate, tangent screen or perimetry. On the basis of collective data from clinical examination and special procedures, the confidence that the patients in the lateralized damage groups (RD, LD) had defects restricted to one hemisphere was high. The DD group represented a diversity of disease, damage, and degree of impairment (table 1).

The LD group included 15 patients who were aphasic on the basis of clinical examination (subjects L-01-09, L-12, L-15, L-16, L-18-20). Some of these LD patients were given a simple demonstration of the requirements of the tasks involved in this study to be certain that they understood the instructions.

Of the subjects referred for participation in the project, 10 were excluded because of severe dementia and inability to cooperate (4 RD, 3 LD, and 3 DD patients). No subject was excluded because of language deficits per se.

The age of the patient and the time of onset (when known) of symptoms were noted. There were no mean age differences between groups. The sample consisted primarily of men, reflecting the population from which the subjects were drawn.

Test procedure. Each patient was tested individually. Consideration was given to fatigue to ensure that each patient put forth the best effort. Three sets of tests were administered.

1. Graham-Kendall Memory-for-Designs Test (MFD).[17] The MFD is a neuropsychologic test consisting of 15 geometric designs that vary in complexity from an equilateral triangle to complicated, unfamiliar designs. Individual designs are shown to the subject for 5 seconds. After each presentation, the subject is asked to draw the design from memory. Order of presentation was the same for each subject. Errors were scored according to seven categories, using the Modified Taylor Scoring System.[18,19] The error categories were: distortion, omission, embellishment, rotation, reversal, perseveration, and disorganization of the order of the designs on the page.

2. Drawings. Each patient was asked to draw (successively and on a clean sheet of unlined 21.5 × 28 cm paper) a daisy, a wagon wheel with spokes, the face of a clock, and two human figures, one of each sex.

On the basis of a blind review of the drawings and the MFD results (table 2), a neuropsychologist assigned each subject to one of the four experimental groups. The confidence with which each rating was made was coded 1 (little or no confidence in the accuracy of the rating), 2 (moderate confidence), or 3 (great confidence). The rater kept no record of the number of subjects he had assigned to each group. Evidence of neglect in the drawings and MFD results was also rated 1 (mild), 2 (moderate), or 3 (severe).

3. Line Bisection (LB). The LB test was specifically designed for this study as follows. Twenty lines were drawn with a No. 00 drafting pen on a sheet of white (21.5 × 28 cm) paper parallel to its long axis (figure 1). Eighteen of the lines were organized in three sets of six lines so that one set of lines lay primarily on the left side of the page, one set lay in the center, and one lay on the right. Each set contained lines of 100 mm, 120 mm, 140 mm, 160 mm, 180 mm, and 200 mm. The lines were organized so that the test was balanced with regard to line length from top to bottom. Two 150-mm lines were placed at the top and bottom (center) of the page to be used in communicating the instructions to the patient. These lines were not included in the data analysis. Thus, the test was designed so that an alternate form (with different order of presentation of lines) could be obtained by rotating the paper 180°. (Previous testing of 38 normal subjects indicated that these were, in fact, comparable forms.)

Administration of the LB test was straightforward. The instructions contained these main points: (1) Use the right (or left) hand; keep the other hand off the table. (2) Cut each line in half by placing a small pencil mark through each line as close to its center as possible. (3) Do not make more than one mark on any line. (4) Mark each of the lines without skipping any. The subject was not allowed to move the page. When necessary, the page was taped to the table top directly in front of him. The form and the hand used (when the subject had the use of both hands) were randomly as-

Table 2. Criteria used for blind analysis and classification of Memory-for-Designs (MFD) and drawings

Group	MFD	Drawings
Right damage (RD)	Errors in organization, especially instances of beginning on the right side of the page and working to the left Shift to the right side of the page for all designs Omission of the left portion of one or more figures	Asymmetry in individual figures, with the left portion of the figure poorly executed Omission of the left portion of the figure Positioning of the figure on the right side of the page
Left damage (LD)	Evidence of perseveration Tendency to write the "name" of the design, e.g., writing "triangle" rather than drawing the figure Evidence of weakness or clumsiness	Perseveration Evidence of weakness and clumsiness
Diffuse damage (DD)	Gross distortion 12 or more errors Many unrecognizable figures Letters or numbers drawn instead of the geometric designs Evidence of tremor	Gross distortion Oversimplification Evidence of tremor
Hospital control (HC)	Well organized Fewer than 12 errors No shift of figures to right side of page No evidence of clumsiness or tremor	No evidence of asymmetry No evidence of tremor or clumsiness No gross distortions or bizarre elements in the drawings

signed. If the subject had the use of both hands, he was then asked to complete the alternate form of the test with the other hand. All lines left unmarked by the subject were noted and subsequently pointed out to the subject. He was then specifically instructed to mark them.

Scoring of the LB test was accomplished in two ways: (1) noting the number and position of neglected (unmarked) lines, and (2) measuring the deviation of the attempted bisection of each of the lines from the true center.

To investigate the average deviation of the attempted bisection from each line's true center, it was necessary to devise a method of adjusting for the differences in line length. Comparable deviation measures were computed according to the following procedure: The length of the left side of the line, i.e., from the left end of the line to the subject's mark, was measured to the nearest half millimeter. That measurement was converted to a standardized score, using the formula below:

$$\text{Percent deviation} = \frac{\text{measured left half} - \text{true half}}{\text{true half}} \times 100$$

This transformation yielded positive numbers for marks placed to the right of center and negative numbers for marks to the left of center.

Average percent deviation scores were computed for the sets of lines at each position on the page and for the whole page combined.

Results. Table 1 presents individual results and descriptive information for each subject. Group results will be presented in the sections to follow.

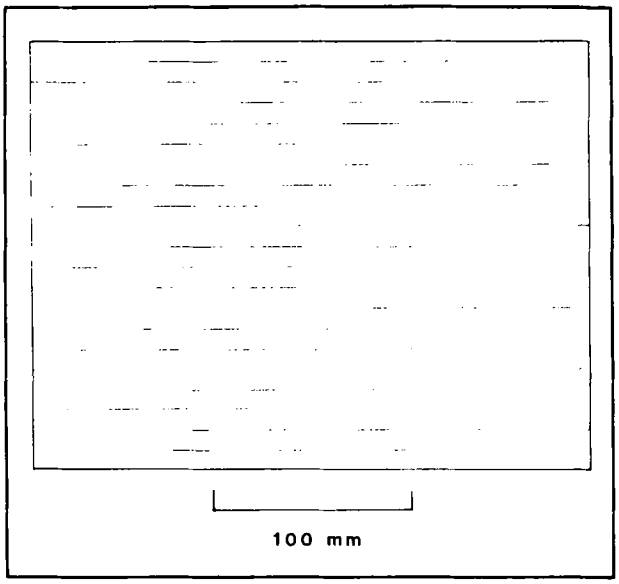

Figure 1. The line bisection test (original outside dimensions are 21.5 × 28 cm).

Reliability. The reliability of various scoring procedures and ratings was evaluated. A detailed account of these findings is not germane, and only a summary is presented here. MFD scoring reliability evaluation yielded a product-moment correlation of 0.99 across the four groups. Reliability of classification of drawings to group membership varied from a low of 63% agreement for the DD group to 86% for the LD group to 100% for the HC and RD groups. (When classifications made with

little or no confidence—code 1—were excluded from the reliability analysis, all groups had 100% agreement, except the DD group, for which the agreement was 71%.)

Reliability of measurement of the left half of each line in the LB test, a simple measurement task, was predictably very high, 0.99+.

Reliability of individual patient performance on the LB test was evaluated using several techniques, e.g., repeated testing of several subjects. Test-retest correlations yielded reliability coefficients in the range of 0.84 to 0.93 for the four groups.

Memory-for-Designs. An analysis of the MFD scores yielded a significant group effect ($p < 0.01$). Subsequent paired comparisons of groups by the Newman-Kuels method indicated that the HC group differed from the damaged groups, but that the RD, LD, and DD groups did not differ from each other.

Taylor[19] suggested a cutoff score of 12 errors as the acceptable upper limit for normal performance. Using this criterion, the following percentages of subjects would be considered to have cerebral dysfunction: RD (94%), LD (80%), DD (88%), and HC (35%). The overall accuracy of classification, using the MFD, was 81%.

Classification from drawings and MFD results. Tables 3 and 4 present the accuracy with which the rater was able to classify subjects on the basis of the drawings and MFD alone. The matrix contains the number of correct judgments along the principal diagonal and all the various combinations resulting in incorrect judgments in the off-diagonal cells. For example, in table 3 the cell in the second row and second column (number 14) represents the number of DD subjects who were correctly classified as DD on the basis of the drawings. The other numbers in the same column represent instances in which the diagnosis of DD was incorrectly made (false positives), and the numbers in the same row are DD patients who received some other diagnosis (false negatives). Any off-diagonal element can be considered either a false positive or a false negative, depending on whether the row or the column is under consideration. The row and column margins contain, respectively, the percentage of cases correctly classified and the percentage of diagnoses that were correct. Two additional statistics, percent effective agreement and the phi coefficient (φ), were also computed and are listed in table 3.

The RD subjects were the most distinctive and the easiest to classify accurately with the relatively crude measures that were used in this part of the study (table 3). There was no confusion between the HC and RD groups, and only a few errors occurred in distinguishing RD subjects from subjects in the DD and LD groups. On the other hand, there was considerable error in distinguishing among the other three groups. Five LD patients were diagnosed as HC patients. Since the rater did not keep track of how many diagnoses of each type he had already made, and rated each protocol independently, the most likely classification was HC and the least likely was LD. The fact that φ was lowest for the LD group is a further indication that the drawings had the least diagnostic efficiency for that group. This seems reasonable, because the tests were ones traditionally used to evaluate the functional integrity of the right hemisphere. The overall rate of correct diagnosis was 76%, a substantial percentage even considering the restricted nature of the study.

When classifications made with "little or no confidence" (code 1) were excluded from table 3, the results were much easier to interpret (table 4). All the percentages were substantially higher than the percentages in table 3. There were still several false positives in the HC column (primarily DD patients who appeared to be normal), but the overall rate of correct diagnosis rose to 89%.

Examination of the relationship between diagnosis of RD and a rating of neglect revealed that left neglect was almost pathognomonic of right-

Table 3. Blind classification of subjects from drawings compared with their actual diagnoses

Actual group membership	Blind classification HC	DD	LD	RD	% of cases correctly classified	% effective agreement	ϕ
HC	17	3	0	0	85	60.7	.670
DD	3	14	1	2	70	53.8	.658
LD	5	2	12	1	60	54.5	.646
RD	0	1	1	18	90	78.3	.837
% of classifications that were correct	68.0	70.0	85.7	85.7			$\bar{\phi}$ = .714*

*Mean ϕ computed using the Fisher r to z_r to transformation.

Table 4. Blind classification of subjects from drawings compared with their actual diagnoses (including only ratings done with moderate or high confidence)

	Before levodopa	Peak effect levodopa	Before bromocriptine
Stage of Parkinson disease (Hoehn and Yahr)	2.60 ±0.08	1.60 ±0.10	3.00 ±0.19
Change from baseline		−38.0% $p < 0.05$	+15.0% $p < 0.05$
Number patients ≥ 1 stage improvement		24	10
Levodopa (mg) in Sinemet		1080 ±65	990 ±59
Mean time (years)		0.50 ±0.03	7.40 ±0.36

hemisphere damage. Ninety percent of the RD subjects had a rating of left neglect, whereas only 5% of the non-RD subjects received a neglect rating. Every rating of neglect in these data was classified as left neglect. The severity of neglect in all three of the non-RD instances of neglect was rated as mild 1.0 (computed on the basis of codes 1, 2, and 3), compared to a mean of 1.8 for the RD patients with neglect. The highest possible average would be 3.0

Line-bisection test. Number of lines totally neglected. In this section, we refer to the number of lines that were left unmarked by the patient. These lines were then pointed out to the subject so that eventually every line on the page was completed.

At least one person in each group neglected a line (table 1). However, neglect of this type was very unusual in the LD, DD, and HC groups.

The performance of the RD patients was strikingly different from the performance of the other three groups. In all, 99 lines were neglected by 15 RD subjects ($\bar{\chi} = 6.6$ for subjects who neglected), and only 14 lines were neglected by 10 subjects in the other three groups ($\bar{\chi} = 1.4$). No subject in the LD, DD, or HC groups neglected more than two lines. Eleven RD subjects neglected more than two lines, and those subjects accounted for 91 neglected lines. Furthermore, there was a strong tendency to neglect lines on the left side of the page. The ratio of neglected lines from left to center to right was 3.4 to 1.8 to 1.0. Analysis of these data by hand used showed no significant difference, suggesting that the probability of neglecting a line is independent of hand used.

The correlation of −.88 between line length and number of lines neglected was significant ($p < 0.02$) and indicated that shorter lines were more frequently neglected than longer lines. No significant relationship was found between vertical position of the line on the page and neglect. More lines were neglected by patients with symptoms of recent onset than by patients with chronic disease, but this relationship was not statistically significant. The relationship between number of lines neglected and neglect ratings derived from the drawings was significant, though moderate ($r = 0.548, p < 0.02$).

Errors in bisecting lines on the LB test. Results in this section are based on the percent deviation scores. Preliminary analysis revealed that line length was not a significant factor as a main effect or in interaction with other factors. Therefore, to simplify this presentation, the means of the lines at each horizontal position (left, center, and right) were used as dependent variables in the analysis. Each subject had either three or six mean scores, depending upon whether he had the use of one hand or both hands.

Analysis of the data for the left hand included 6 RD, 19 LD, 19 DD, and 20 HC patients (figure 2). There were no significant paired differences in these data. There was a tendency to mark lines to the left of center with the left hand regardless of group affiliation or line position. However, because there were no significant paired differences, performance with the left hand on this task was not a good discriminator of group identity.

Analysis of the data for the right hand (figure 3) included 19 RD, 8 LD, 19 DD, and 20 HC subjects. Analysis of variance yielded significant F ratios for group and line position effects ($p < 0.03$ and $p < 0.001$, respectively) and the interaction between the main effects ($p < 0.001$). Because the interaction was significant, simple main effects were analyzed. The groups differed significantly on the left lines ($p < 0.001$) and center lines ($p < 0.001$) but not on the right set of lines. In examining the

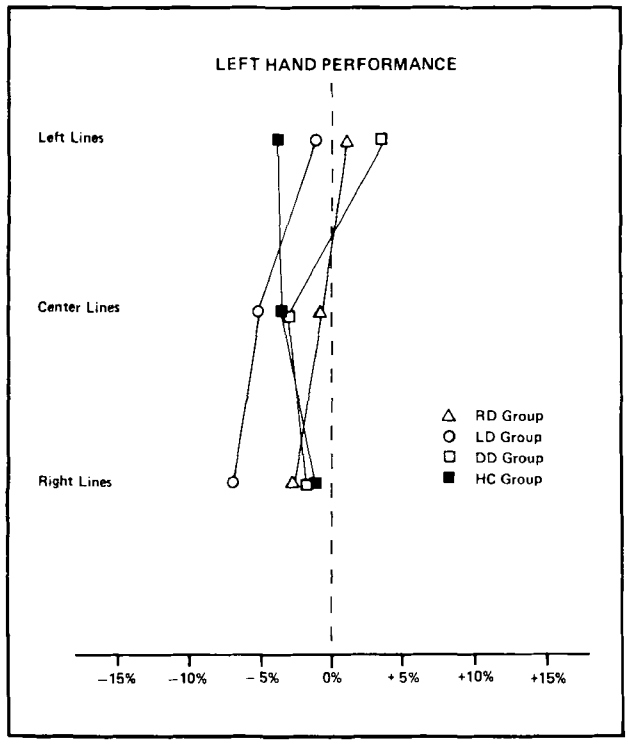

Figure 2. Mean percent deviation scores on the LB test for the left hand for left, center, and right sets of lines. Number of subjects in each group is as follows: RD (6), LD (19), DD (19), HC (20). Positive numbers indicate marks to the right of center and negative numbers indicate marks to the left of center. *Subjects R-13 and L-08 were excluded from figures 2 and 3 and all associated computations owing to their apparent poor cooperation with or lack of understanding of the instructions. Subject DD-17 did not have the use of his left hand.*

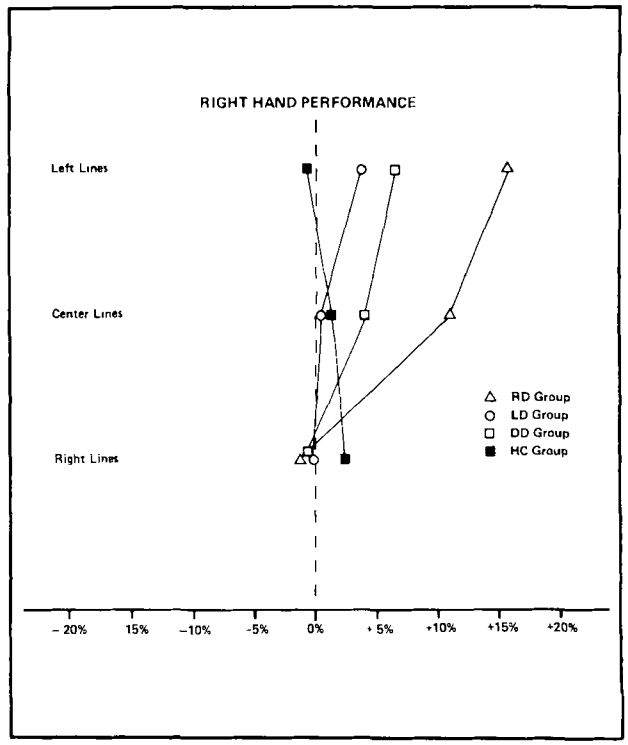

Figure 3. Mean percent deviation scores on the LB test for the right hand for left, center, and right sets of lines. Number of subjects in each group is as follows: RD (19), LD (8), DD (19), HC (20). Positive numbers indicate marks to the right of center and negative numbers indicate marks to the left of center. *Subjects R-13 and L-08 were excluded from figures 2 and 3 and all associated computations owing to their apparent poor cooperation with or lack of understanding of the instructions. Subject DD-08 did not have the use of his right hand.*

group mean differences, the RD group differed from the other three groups for the left ($p < 0.001$) and center ($p < 0.001$) sets of lines. The difference was in the expected direction, i.e., center estimates were shifted to the right of true center. There was no difference between groups for the right set of lines, which lay in the visual field that hypothetically should be unaffected by left neglect.

Discussion. The results described above allow us to comment on two specific issues: (1) frequency of neglect in patients with cerebral disease, and (2) the value of the line bisection task in identifying patients with unilateral cerebral damage.

Frequency of neglect. In this study, indications of neglect included: neglect of two or more whole lines on the LB test (pilot data on a sample of 38 college students suggested that missing one line was possible, although unusual, in a normal sample), extreme mean deviations on the LB test estimates of center, and estimate of neglect from the drawings.

By group, the numbers of patients who showed these tendencies were RD (19), LD (3), DD (4), and HC (0). Reports in the literature of neglect in left-hemisphere-damaged patients range from 2% to 15%.[10,20] Among 59 patients with unilateral neglect, Hecaen[10] noted that 4 had left hemisphere disease and that 3 of the 4 were left-handed. The issue of neglect in the DD group is more complex. There are no comparable estimates from other studies. The closest comparison is a rate of 8% among patients with bilateral disease.[21] In Hecaen's study,[10] 4 of the 59 patients with neglect had bilateral damage.

Both the literature and the results of our study indicate that it is possible for an occasional individual with cerebral disease not in the right hemisphere to show unilateral visual neglect. However, the incidence of neglect in those patient groups is low. Goldstein[22] suggested a general narrowing of the attentional field in brain-injured patients, and our results tend to support his observation. Patients in the LD and DD groups who neglected more than one line typically neglected lines on both sides of the page. Depending on the

measure used, there seemed to be indications of left or right neglect among the LD subjects. In addition, the tendency of every group of brain-damaged subjects was to make line transections toward the center of the page, i.e., marking too far to the right on left lines and vice versa. In contrast, the HC subjects tended to mark away from the center of the page.

Estimates of incidence of neglect in the RD group ranged from 90% (neglect on drawings) to 55% (neglect of more than two lines) to 30% (patients with extreme deviations to the right of center on the left lines using the right hand). Earlier reports estimated incidence of neglect in RD subjects as 33%,[21] 44%,[20] and 66%.[23] The nature and subtlety of the tasks presented to the patient and the degree of asymmetry in the patient's performance required to diagnose "neglect" all contributed to the discrepancies among the incidence figures. It appears, however, that with appropriate measures, neglect can be identified in a majority of patients with damage or disease of the right hemisphere and that neglect may be as common in right-hemisphere-damaged patients as language disorders are in left-hemisphere-damaged patients.

Value of the line bisection test. Since 1915, when Axenfeld[13] suggested the idea of line bisection to evaluate patients with suspected visual neglect, the technique has been considered an effective clinical approach, but it has not been investigated in a statistical, formalized manner in the past. Our data suggest that the test can differentiate between groups of patients under special conditions, i.e., using the right hand with the left set of lines. Further, total neglect of more than two lines on our test, regardless of hand used, identified RD patients. It seems unlikely, however, that asking a patient to bisect a single horizontal line will yield information of reliable clinical utility. Even with the complex stimulus we employed, individual patients would have been incorrectly classified by line bisection alone, although such an artificial restriction of the number of evaluation approaches would not be imposed in a true clinical situation.

Acknowledgments

We thank colleagues who referred patients to us for inclusion in this study. We also thank Dr. L. W. Jarcho for his careful review of the manuscript and Ms. Linda Broadhead for her assistance in typing the manuscript.

References

1. Critchley M: The Parietal Lobes. London, E. Arnold and Company, 1953
2. Holmes G: Disturbances of visual space perception. Br Med J 2:230-233, 1919
3. Jackson H: Case of large cerebral tumour without optic neuritis and with left hemiplegia and imperception. Roy Ophthal Hosp Rep 8:434-444, 1876. Cited in Benton AL: The "minor" hemisphere. J Hist Med 27:5-14, 1972
4. Benton AL: The "minor" hemisphere. J Hist Med 27:5-14, 1972
5. Weinstein EA, Friedland RP (Editors): Advances in Neurology: Hemi-Inattention and Hemisphere Specialization. New York, Raven Press, 1977
6. Brain WR: Visual disorientation with special reference to lesions of the right cerebral hemisphere. Brain 64:244-272, 1941
7. Paterson A, Zangwill OL: Disorders of visual space perception associated with lesions of the right cerebral hemisphere. Brain 67:331-358, 1944
8. Battersby WS, Bender MB, Pollack M, et al: Unilateral "spatial agnosia" ("inattention") in patients with cerebral lesions. Brain 79:68-93, 1956
9. Gainotti G: Les manifestations de négligence et d'inattention pour l'hemispace. Cortex 4:64-92, 1968
10. Hecaen H: Clinical symptomatology in right and left hemisphere lesions. In Mountcastle VB (Editor): Interhemispheric Relations and Cerebral Dominance. Baltimore, Johns Hopkins Press, 1962
11. Albert ML: A simple test of visual neglect. Neurology (Minneap) 23:658-664, 1973
12. Rosenberger PB: Discriminative aspects of visual hemiinattention. Neurology (Minneap) 24:17-23, 1974
13. Axenfeld T: Hemianopische Gesichtsfeldstörungen nach Schädelschüssen. Klin Monatsbl Augenheilkd 55:126-143, 1915. Cited in Critchley M: The Parietal Lobes. London, E. Arnold and Company, 1953
14. Brain WR: Speech Disorders: Aphasia, Apraxia and Agnosia. Washington, Butterworths, 1965, p 192
15. Kleist K: Gehirnpathologie. Leipzig, Barth, 1934
16. Diller L, Weinberg JP: Hemi-inattention in rehabilitation: The evolution of a rational remediation program. In Weinstein EA, Friedland RP (Editors): Advances in Neurology: Hemi-Inattention and Hemisphere Specialization. New York, Raven Press, 1977
17. Graham FK, Kendall BS: Memory-for-Designs test: Revised general manual. Percept Mot Skills 11:147-188, 1960
18. Grundvig JL, Needham WE, Ajax ET: Comparison of different scoring and administration procedures for the Memory-for-Designs test. J Clin Psychol 26:353-357, 1970
19. Taylor FR: A revised scoring system for the Graham-Kendall Memory-for-Designs test. Unpublished master's thesis, University of Utah, 1961
20. Gainotti G: Studies on the functional organization of the minor hemisphere. Int J Ment Health 1:78-82, 1972
21. Benton AL: Disorders of spatial orientation. In Vinken PJ, Bruyn GW (Editors): Handbook of Clinical Neurology. Amsterdam, North-Holland Publishing Company, 1969, vol 3, pp 212-228
22. Goldstein K: Aftereffects of Brain Injuries in War. New York, Grune & Stratton, Inc, 1948
23. McFie J, Zangwill OL: Visual-constructive disabilities associated with lesions of the left cerebral hemisphere. Brain 83:243-260, 1960