

## Visuospatial Neglect: The Ultimate Deconstruction?

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Unilateral visuospatial neglect is now widely acknowledged to be a highly heterogeneous condition: The overt manifestations of visual neglect can vary as a function of task, spatial domain, and mode of response (at least). Double dissociations (sometimes of the strong form) have already been reported between most of the components of what was originally thought to be a relatively stable construct within the visual modality. Nonetheless, throughout successive fractionations of neglect, reported cases of bidirectional task-specific neglect after unilateral brain damage are rare. We now report two such cases. After right hemisphere stroke, the first patient reliably showed severe left neglect on cancellation but right neglect on line bisection. After left hemisphere stroke, the second case showed right neglect on cancellation but left neglect on line bisection. Extensive investigation of case 1 confirmed our previous conjecture that the crucial distinction between these tasks lies in the presence or the absence of an overt target. In contrast to cancellation, line bisection demands the internal computation of the location of the “target” (the midpoint), followed by executing a motor response toward the precise location of that “imaginary” midpoint. The relative attentional and premotor contributions of the intact and damaged hemispheres to these forms of bidirectional neglect are also assessed. © 1998 Academic Press

### INTRODUCTION

It is not in dispute that unilateral visuospatial neglect is consequent upon right hemisphere pathology in much the same sense that aphasia is a left hemisphere pathology. That is, severe, chronic left neglect is frequently seen

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after right hemisphere stroke, while comparable right neglect after left hemisphere stroke is rare. It is also not in dispute that there are dissociable behavioral subtypes of (left visuospatial) neglect (McGlinchey-Berroth et al., 1996). The most convincing evidence that "neglect is not a unitary disorder" (Heilman et al., 1994) comes from pairs of patients who show double dissociation on two tasks that are widely accepted as appropriate measures of unilateral neglect. Classic double dissociations, where one patient performs task A within normal limits but is severely impaired on task B, while another patient shows the opposite pattern, are *prima facie* evidence that independent processes are responsible for the two tasks.

Halligan and Marshall (1992) demonstrated a reliable classic double dissociation between line bisection and cancellation (prototypical "neglect" tasks) in two patients with unilateral right hemisphere stroke. Supporting evidence, with larger groups of patients, has been reported by Binder et al. (1992) and McGlinchey-Berroth et al. (1996). Current accounts of hemispheric specialization in relation to the lesions that provoke visuospatial neglect seem, however, to rule out the possibility of most forms of bidirectional, task-specific neglect after unilateral hemispheric damage. That is, it appears highly unlikely that patients using their right ipsilesional hand would present with, for example, *left* neglect on cancellation but *right* neglect on line bisection (Marshall & Halligan, 1996).

Patients with bidirectional neglect, as defined, are, of course, found after *bilateral* brain damage (Humphreys & Riddoch, 1994). In such cases, it is plausible to propose that the way in which different cognitive tasks modulate attentional orienting "may depend in part on the extent to which particular regions within a hemisphere became activated during processing" (Reuter-Lorenz et al., 1990). Thus a left anterior lesion may provoke right neglect on one task, while a co-occurring right posterior lesion provokes left neglect on another task. In these instances, the typical pattern of performance is right neglect on cancellation and copying tasks in association with left neglect on reading (Riddoch et al., 1995). The "anomalous" neglect dyslexia then receives the interpretation that even a damaged left hemisphere can orient strongly to the right side of space when language tasks are involved. A related line of argument has been taken in cases of bidirectional neglect after *left* unilateral lesion. This argument, however, is not open in those cases of unilateral right hemisphere brain damage: accordingly, the presumption is that bidirectional neglect will not be found after lesions restricted to the right hemisphere.

Nonetheless, there are suggestions in the literature that the co-occurrence of left neglect on cancellation and right neglect on line bisection is possible after unilateral right hemisphere lesion even when the right hand is used (Robertson et al., 1994; Tromp, 1995). For example, patient DW reported in Halligan and Marshall (1988) placed his bisections significantly to the left of center on line lengths of 279 and 245 mm. Case 12 of Mattingley et al.

(1994) showed a similar pattern, as did cases b85, r32, and r43 of Robertson et al. (1994), despite showing left neglect on other visuomotor tasks. Another right-brain-damaged patient reported by Werth (1988) bisected 50- and 100-mm line lengths considerably to the left of the midpoint despite showing severe left-sided neglect on other tasks. Unfortunately, these putatively anomalous cases were not investigated in sufficient detail, and it is possible that indications of right neglect in other patients have been averaged out statistically over subjects and over line lengths within subjects (Tromp, 1995).

Accordingly, the current studies further explore the nature of bidirectional (task-specific) neglect in two cases of unilateral stroke. The first patient sustained a right hemisphere stroke, and the second, a left hemisphere stroke. Case 1 will be described in detail. The second case, on whom we only have minimal data, is reported in the Appendix.

### CASE DESCRIPTION

MF is a 72-year-old right-handed woman who was initially referred to the Radcliffe Infirmary following an acute onset of vomiting, disorientation, and memory loss in early October, 1993. She had been found lying motionless on her bed looking pale and unwell. Her main complaints were of visual loss, confusion, and difficulties in looking after herself. Over the next few days, she got worse and it was also noted that she tended to walk into the left side of doors. On examination, there were no problems with speech output, verbal comprehension, or sensation. There was no evidence of motor weakness. Eye movements were normal and perimetry showed no evidence of a visual field deficit. Nonetheless, there was reliable left side extinction (both tactile and visual) and left neglect on copying, drawing, and cancellation tasks (Figs. 1a–1c).

On tests of mental orientation (Mini-mental test score 27/30; Hodkinson Mental Test Score 7/10) she performed within normal limits. Assessed by an occupational therapist, on November 2, MF showed left neglect on many everyday tasks including cooking, dressing, and walking. This impairment persisted throughout later sessions of occupational therapy. She was unable to locate cutlery in the left side of a drawer, she often missed people on her left side, and she needed to be constantly reminded to check items on the left when cooking. CT scans on November 2 and December 22 revealed a resolving haemorrhage involving the right parietal region (Fig. 2 shows the first scan).

#### *Neuropsychological Assessment*

More detailed neuropsychological testing began on November 16, 1993, and continued over the following 8 months until July 1994. During this time MF received no formal rehabilitation for her neglect. Assessed on three sub-

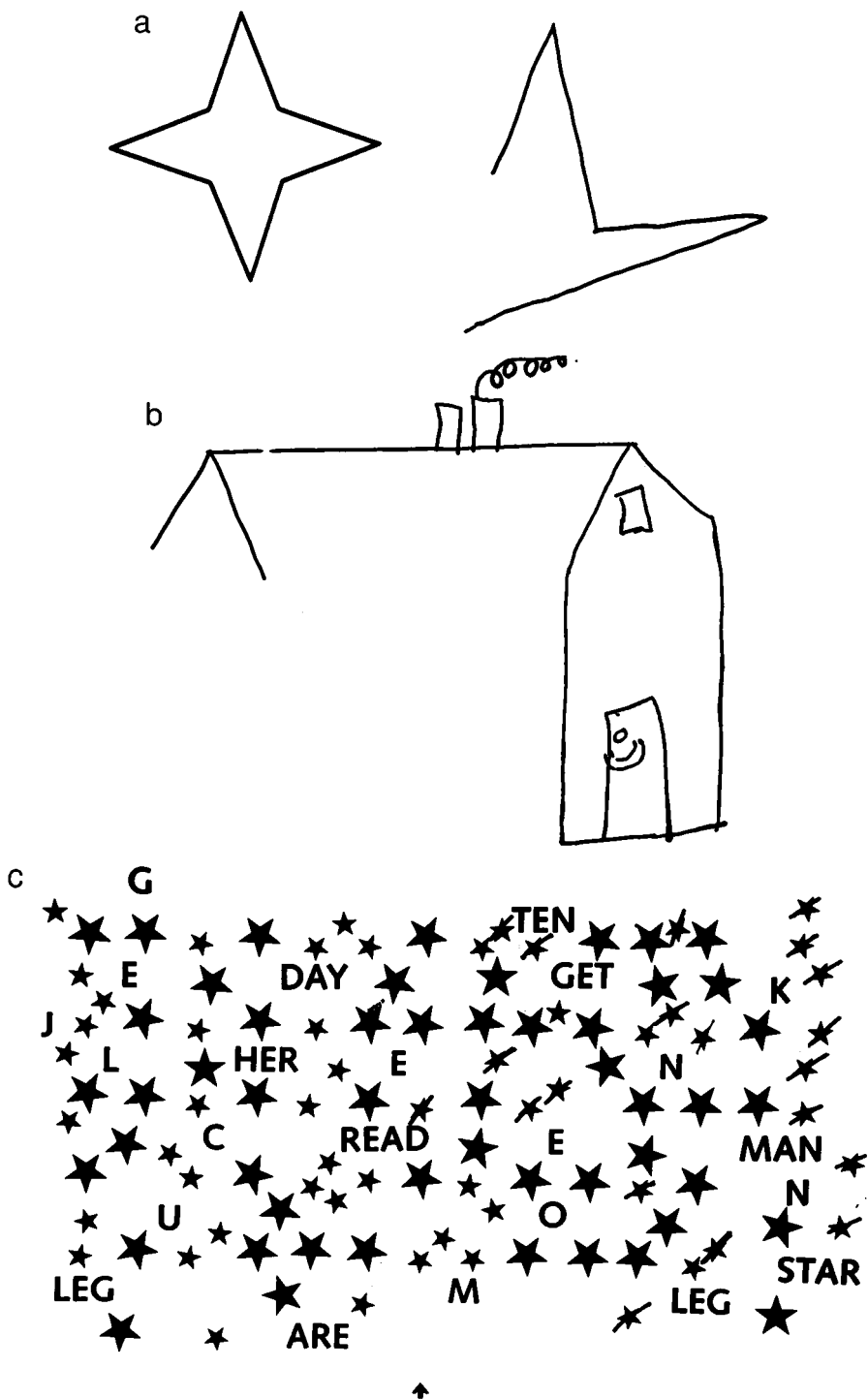


FIG. 1. (a-c) Illustrations of MF's left neglect on copying, drawing, and cancellation.



**FIG. 2.** CT scan showing the haemorrhage which involved the right parietal region.

tests of the Visual Object and Space Perception Battery (Warrington & James, 1991), MF's performance was within normal limits on Dot Counting and just outside the 5% cutoff (17/20) for Position Discrimination (reporting the relative position of objects in two-dimensional space) and Number Location (6/9).

There was no evidence of anosognosia (Cutting, 1978), autopagnosia, or simultanagnosia. Optic ataxia was initially assessed by pointing (with the eyes open) to targets in peripersonal space. Small targets (dots on an A4 page) were included in this assessment. There was no suspicion of optic ataxia. A few trials of pointing with the eyes closed to previously seen objects were also undertaken and revealed no obvious impairments. Extinction per-

sisted: In the tactile modality, MF detected all unilateral stimuli on the left (10/10) and right hands (10/10), respectively. Yet on double simultaneous stimulation she detected none of the stimuli on the left hand (0/10). While maintaining fixation, MF had no difficulty in detecting unilateral visual stimuli presented in either her left (14/14) or right (14/14) field. However, on simultaneous stimulation she detected only one of the stimuli (1/16) on the left.

On the Behavioural Inattention Test (Halligan et al., 1991) MF obtained a score of 94/146; the cutoff for normal performance is 130/146. Line cancellation was 36/36; letter cancellation was 13/40; star cancellation was 38/54; figure copying was 0/4; line bisection 6/9; and representational drawing 1/3. On cancellation tasks, she always began on the right side and on drawing tasks positioned the drawn objects on the right side of the page. She showed no neglect on single-word reading (20/20), text reading, word copying (42/42), or text writing. Requested to mark the location of well-known cities and towns on outline maps of the British Isles and the United States, MF tended to transpose cities from the left side (West) over into the right of the map (East). Although most of her omissions on the BIT subtests (letter and star cancellation, drawing, and copying) clearly involved the left (contralesional) side, the most striking peculiarity of the initial clinical examination was her performance on line bisection. Asked to bisect 10 lines, each of 180 mm and individually presented on separate sheets of A4, she showed a significant and reliable deviation to the *left* of true center, suggestive of right neglect.

## EXPERIMENT 1

The first experiment assessed the reliability of MF's differentially lateralized performance on line bisection and cancellation tasks.

### *Materials and Method*

Five cancellation tasks, each of which contained 64 targets embedded within a background of distracting foils, were administered. Interleaved with the cancellation tasks, in an ABABABABAB design, the patient was presented with a set of five blocks of line bisection, each comprising 10 lines per block. In order to reduce practice effects, the specific targets and foils were changed for each of the five cancellation tasks, although the spatial loci of the designated targets for cancellation were identical. This same experiment was repeated 6 weeks later using a different set of five comparable cancellation tasks with 48 targets and the same line length for bisection. In all instances, the A4 stimulus sheet was presented on the desk top and centered on the patient's midsagittal plane. No time limit was imposed and the patient put down her pen when she was satisfied that all targets were cancelled. For scoring, the targets were grouped into four columns from left to right (Session 1) and six columns from left to left to right (Session 2).

The horizontal line bisection task required the patient to mark the center of 10 black 180-mm lines (1 mm in width), each presented individually and centered both horizontally and vertically on a sheet of A4 paper (298 × 208 mm). Each stimulus sheet was centered on the midsagittal plane of the patient's trunk.

TABLE 1  
The Results of the First Interleaved Cancellation/Bisection Sequence of Tasks

Line bisection (180-mm lines $\times 10$ ) Mean deviation	Cancellation (No. of correct responses)				Total score/64
	Left		Right		
	16	16	16	16	
-30.0 (13.5)	0	2	14	16	32
-34.5 (13.7)	0	3	13	16	32
-35.2 (10.7)	0	0	13	16	29
-25.9 (9.4)	0	0	12	16	28
-18.2 (7.9)	1	13	11	16	41

### Results

The results for the two testing sessions (both tasks) are displayed in Tables 1 and 2. The number of omissions on the left and right sides of the page are shown for each trial. For line bisection, transection accuracy was measured to the nearest millimeter and expressed as positive (+) for rightward and negative (-) for leftward displacements. The results are shown in Tables 1 and 2.

It can be seen that many more targets were cancelled on the right than the left half of the arrays, and yet bisections are grossly displaced to the left of true center. The overall result is that when MF performs cancellation, she reliably shows contralesional (left) neglect, while at the same time demonstrating reliable ipsilesional (right-sided) neglect (i.e., left-sided deviation) on line bisection. This qualitatively distinct performance was maintained throughout all subsequent sets of cancellation and bisection tasks ( $N = 10$ ) that she was given over a 6-month follow-up period.

MF's unexpected performance on line bisection (compared to all other

TABLE 2  
The Results of the Second Interleaved Cancellation/Bisection Sequence of Tasks

Line bisection (180-mm lines $\times 10$ ) Mean deviation	Cancellation (No. of correct responses)						Total score/48
	Left			Right			
	8	8	8	8	8	8	
-21.4 (10.5)	0	1	4	7	4	8	24
-14.3 (9.7)	0	3	6	7	8	8	32
-10.2 (9.4)	3	6	6	5	7	8	35
-28.0 (10.4)	1	2	2	6	8	8	27
-23.1 (8.9)	0	4	7	6	7	8	32

TABLE 3  
The Order of the Cancellation Testing Sequence as Described in Experiment 2

Cancellation (Order, hand, and side of start)	Total number of targets						Total score (of 54)
	Left			Right			
	8	8	11	11	8	8	
(a) Right hand/right side	0	0	6	9	7	8	30
(c) Right hand/left side	0	2	10	7	6	6	31
(b) Left hand/right side	3	3	10	10	8	8	42
(d) Left hand/left side	0	2	9	11	8	8	38

tests of neglect that she was given) led us to attempt to characterize the nature and reliability of this bidirectional performance. In all the following experiments (conducted over an 8-month period) the patient used her right hand unless stated otherwise.

## EXPERIMENT 2

We first investigated the extent to which implicit and explicit cues could effect MF's bisection and cancellation performance. We examined how (a) lateralized spatial cues (side of start) and (b) relative hemispheric activation (use of the left or right hand) modulated performance on both tasks.

### Method

The Star Cancellation task from the BIT was used (Halligan et al., 1991). This comprises 54 small target stars in the context of distractors randomly distributed across the page. For scoring purposes, the test can be divided into three columns on the left and three on the right of the page. As before, no time limit was imposed and the A4 stimulus sheet were presented on the desk top centered on the patient's midsagittal plane.

Horizontal line bisection, using 180-mm lines in blocks of 10, was performed. The procedure was similar to that of Experiment 1 except that now the position of the responding arm was varied prior to each bisection. As MF's performance on line bisection was the puzzle, we repeated this task twice to assess reliability.

### Results

The order of the cancellation testing sequence is indicated in Table 3. Although use of the left hand (starting on the left or right side) helps to reduce *left* neglect, MF nevertheless continues to omit nearly 30% of targets on the left side.

The order of the bisection testing sequence is shown in Table 4. Given that MF shows reliable ipsilesional *right neglect* in the standard condition (right hand/right side), it might be expected that use of the left hand and left side start would increase this aberrant deviation as both variables could activate the leftward orientational bias of the right hemisphere. However, as



TABLE 4  
The Sequence and Extent of Deviation on the  
Line Bisection Task Described in Experiment 2

Line bisection	Order and deviation
Right hand/right side	(a) -27.1 (13.6)
Right hand/left side	(b) -21.9 (4.1)
Left hand/left side	(c) -18.9 (8.1)
Left hand/right side	(d) -14.7 (8.1)

far as hand use is concerned, the results tend in the opposite direction. A two-way ANOVA ( $F = 7.25$  ( $df = 1, 39$ )  $p < .01$ ) revealed that *hand used* was the only significant effect. Thus, use of the left hand (which activates the right hemisphere), irrespective of starting position, significantly reduces the leftward deviation (but severe right neglect nonetheless remains).

### EXPERIMENT 3

To establish if MF's performance on line bisection is influenced by explicit attentional cueing (Riddoch & Humphreys, 1983), we investigated the extent to which drawing the patient's attention to preexisting markers at the ends of the line just prior to bisection would modulate the extent of deviation from true center.

#### Method

The patient was required to attend to the left and right ends of the line prior to bisection by reading aloud the randomly selected letter(s) located there on each trial.

#### Results

The results of using perceptual cues are shown in Table 5. It can be seen that merely drawing attention to the left or right end points, although sufficient to bring about a significant reduction after reading the right letter ( $F = 5.9$ ,  $df = 3, 39$ ,  $p < .003$ ), was not sufficient to negate the leftward deviation of MF's transections.

TABLE 5  
The Results of Using Perceptual Cues on Line  
Bisection Performance

Line bisection/condition	
Standard	-33.6 (11.5)
Read letter right end	-16.0 (4.3)
Read letter left end	-23.6 (5.6)
Standard	-23.0 (13.0)

TABLE 6  
The Effects of Hemispatial Positioning on Line Bisection

	Left	Middle	Right
180 mm × 10	-41.9 (19.7)	-47.8 (11.9)	-58.2 (13.5)

#### EXPERIMENT 4

The next experiment examined the effects of hemispatial position on MF's line bisection performance (Heilman & Valenstein, 1979; Halligan & Marshall, 1995).

#### *Method*

In the "left space" condition, the right edge of the A4 sheets (each containing one horizontal line) was centered at the patient's midline. In the "central" condition, the midpoint of the page was centered on the patient's midsagittal plane. In the "right space" condition, the left edge of the A4 page was centered on the patient's midline. In all other respects, the method and design were identical to those of the previously reported studies of bisection.

#### *Results*

It can be seen from Table 6 that there is a strong effect of hemispatial positioning for the 180-mm lines. Positioning the page in left contralesional space reduces the extent of leftward deviation, while right hemispace increases the leftward deviation. There was a significant difference between performance across hemispace ( $F = 5.71$ ,  $df = 2, 29$ ,  $p < 0.01$ ). *Post hoc* comparisons revealed that performances in left and right hemispace were significantly different on the Scheffe  $F$  test at the 95% level.

#### EXPERIMENT 5

We next required MF to judge prebisected lines (Landmark test). It is widely argued that performance on this test is a "pure" measure of "perceptual" neglect, without motor involvement (Milner et al., 1993; Marshall & Halligan, 1995).

In quasi-random order, MF was presented with 50 individual lines of 180 mm. Each one was pretransected: 10 at -15 mm from true center, 10 at -10 mm, 10 at  $\pm 0$  mm (correctly bisected), 10 at +10 mm, and 10 at +15 mm. After each line was presented, MF was required to say whether she thought it was correctly bisected (or not). The results are shown in Table 7. It can be seen that performance is good. Only two errors were made, one at +10 mm and one at +15 mm, where these transections were judged as correct bisections. This pattern is indicative of *mild* left neglect.

TABLE 7  
The Results of the Landmark Test (Judging  
Prebisected Lines)

	Position of pretransected deviation (mm)				
	-15	-10	0	+10	+15
No. correct:	10/10	10/10	10/10	9/10	9/10

## EXPERIMENT 6

Previous studies have shown that transection displacement (and variance) in neglect is a function of line length. To ascertain whether this was true for MF, horizontal line bisection was performed using 10 line lengths (each 1 mm in width) that varied from 18 to 180 mm in steps of 18 mm.

### Methods

As in Experiment 1, each line was presented individually and centered horizontally and vertically on a sheet of white A4 paper. Each stimulus length was presented 10 times with order of presentation pseudo-randomized across lengths. This task was repeated on three occasions, the first separated from the last by 6 months.

### Results

The results are shown in Table 8.

The linear regression equations for the signed and the absolute displace-

TABLE 8  
The Mean and Standard Deviation for Three Testing Sessions Using Randomized Line  
Lengths That Varied between 18 and 180 mm

Line length (mm) (Right hand/ right side)	(1) 15/12/93		(2) 4/2/94		(3) 7/6/94	
	Signed	Absolute	Signed	Absolute	Signed	Absolute
180	-7.7 (6.8)	9.1 (4.5)	2.5 (7.2)	5.1 (5.4)	2.1 (6.2)	4.3 (4.8)
162	-11.6 (6.1)	11.6 (6.1)	-1.5 (6.4)	4.9 (4.1)	2.9 (5.9)	4.5 (4.7)
144	-9.6 (6.4)	9.6 (6.4)	1.9 (7.5)	5.5 (5.2)	2.9 (4.7)	4.3 (3.3)
126	-9.7 (9.1)	9.7 (9.1)	0.4 (7.6)	4.6 (5.3)	2.5 (5.9)	4.7 (4.1)
108	-13.3 (4.9)	13.3 (4.9)	-5.5 (4.7)	6.1 (3.8)	3.9 (5.7)	4.9 (4.7)
90	-10.7 (6.1)	10.7 (6.1)	-0.8 (4.5)	3.3 (2.4)	0.7 (4.8)	3.5 (3.2)
72	-11.4 (5.3)	11.4 (5.3)	-3.8 (2.3)	4.4 (3.5)	-0.6 (3.53)	2.6 (2.3)
54	-8.5 (2.3)	8.5 (2.3)	-4.7 (3.7)	5.1 (3.1)	-1.6 (2.83)	2.6 (1.8)
36	-5.8 (2.6)	5.8 (2.6)	1.5 (2.6)	2.1 (2.0)	-1.4 (2.17)	2.0 (1.6)
18	-3.4 (0.6)	3.4 (0.6)	-1.5 (0.7)	1.5 (0.7)	-0.7 (0.95)	0.9 (0.7)

TABLE 9  
 Linear Regression Equations for Signed and Absolute Transection Displacement as a  
 Function of Line Length for the Three Testing Sessions

	(1)	(2)	(3)
	Signed	Signed	Signed
Displacement regression (% Variance)	$-6.42 - 0.027x$ (26%) Absolute	$-3.01 + 0.018$ (13%) Absolute	$-1.94 + 0.030$ (67%) Absolute
Displacement regression (% Variance)	$1.147 + 0.032x$ (36%)	$2.348 + 0.0193$ (49%)	$1.286 + 0.021$ (77%)
SD Regression (% Variance)	$-1.32 + 0.037x$ (66%)	$0.71 + 0.040$ (83%)	$1.22 + 0.037$ (84%)

ment of transections as a function of line length (with the proportion of variance accounted for) are reported in Table 9. The linear regression for standard deviation as a function of line length, is also shown.

Inspection of the control data presented in Manning et al. (1990) shows that the multiplier that defines MF's (signed) performance is within normal limits. The intercept value for the signed regressions is larger than in any of our control subjects and on all three readings with MF is negative. These negative intercepts are indicative of "overshoot" (with right start), as previously found when MF bisects lines of one length (180 mm). The most striking aspect of Experiment 6 nonetheless remains that MF performs in a relatively normal fashion (compared with her grossly abnormal performance on all the other bisection tasks we have reported).

## EXPERIMENT 7

The results of Experiment 3 showed that a perceptual cue (a letter to be read aloud) positioned at either end of the line did little to negate the extent of leftward deviation. In Experiment 7 we investigated whether requiring the patient to make an explicit manual mark at either (or both) end(s) of the stimulus line would influence transection accuracy (Werth, 1993). As before MF was presented with lines of 180 mm.

### Methods

Using the right hand, MF was required (immediately prior to bisection) to mark with a small cross the designated end or ends of the line to be bisected. This experiment was carried out on two separate occasions.

### Results

The order of the testing sequence and the results of the motor cues are shown in Table 10. Explicitly marking the ends of the line prior to bisection

TABLE 10  
The Results of the Motor Cues on Line Bisection Performance

Cueing strategy	Mean deviation (1)	Mean deviation (2)
Standard	-27.5 (7.3)	-42.9 (15.3)
Mark both ends	(a) 0.4 (7.3)	(c) 0.7 (2.0)
Mark right end	(b) 2.8 (5.8)	(b) 1.7 (5.7)
Mark left end	(c) -5.2 (5.5)	(a) -11.8 (5.7)
Standard	-26.5 (11.0)	-28.2 (8.9)

brings MF's performance within normal limits on five of six blocks. Thus the process of marking either end of the line reduces MF's bisection error significantly. When she marks both ends (or just the right end) there is no neglect.

We have already established (Experiment 3) that perceptual cueing per se does *not* improve MF's performance on bisection. It follows that some aspect of the manual movement was responsible for improvement in Experiment 7. To confirm this we asked the patient to perform an additional experiment with an "invisible ink pen" that made no visible mark on the stimulus line, but which could later be made visible by chemical treatment. This ensured that there was no possibility that the patient was biased by any visual residue of her prior transections. The method and procedure were otherwise identical. The design (ABA) was as follows: First, the patient bisected 10 180-mm lines with a normal pen (standard). Then, with the invisible pen, she marked the right end of another 10 180-mm lines and bisected them. Finally, the standard control (10 lines to be bisected with a normal pen) was repeated. The results were as follows: Standard visible -21.4 (9.5); mark right end (invisible) +1.6 (6.9); standard visible -23.8 (12.2). It would appear that the *motor process* of marking the end points produces the remarkable reduction in MF's leftward deviations.

## GENERAL DISCUSSION

Several cases have been published in which the side of space neglected varies according to the task performed by the patient. For instance, Costello and Warrington (1987) reported the case of a right-handed man (JOH) who suffered a *bilateral* lesion as a result of a parietooccipital tumor which extended across the corpus callosum. On line bisection and copying, JOH demonstrated *right* neglect, but when reading single words, there was *left* neglect. Costello and Warrington argued that visuospatial tasks (line bisection and copying) result in right hemisphere activation and leftward orienting of attention, with consequent right neglect. Reading tasks, by contrast, produce strong left hemisphere activation and rightward orienting of attention, causing left neglect.

A case showing similar patterns of dissociation after *unilateral* lesion was reported by Cubelli et al. (1991). Their patient (AR) suffered a *left* parieto-occipital lesion, resulting in mild dysphasia, severe right hemiparesis, and a dense right homonymous hemianopia. AR neglected the right side of space in visuospatial tasks (e.g., copying, line cancellation, and figure search), but the left side was neglected in reading single words. Cubelli et al. (1991) conclude that "the left-neglect in reading, suffered by AR, was an independent deficit to the right-neglect apparent in spatial tasks."

MF contrasts with these and other cases Riddock et al. (1995) in (at least) the following ways: She has a unilateral lesion of the right hemisphere; the directional dissociation she shows was demonstrated to be reliable and persistent when using her right hand; the two tasks that provoke differentially lateralized performance are traditional tests of visuospatial neglect that, until recently, were assumed to be measuring the same underlying construct. Left hemisphere language tasks (e.g., reading) are *not* involved in the dissociation. With respect to task differences that are potentially relevant to MF's performance, we note that in line bisection, there is no physical target visible at the midpoint of the line to distinguish the midpoint from any other position on the line; the midpoint has to be computed on the basis of the (physically detectable) end points of the stimulus line (and the extent between them). The importance of these task differences between cancellation and bisection has been observed in several studies (Pizzamiglio et al., 1992; McGlinchey-Berroth et al., 1996). In the case of MF's performance, it can readily be seen that her manual bisections (Experiment 1) are significantly to the left of the position that would be predicted from her bisection judgements. The principle component of MF's "neglect" on line bisection may thus be "premotor" (Rizzolatti and Berti, 1993). However, this motor/premotor component cannot be described as a directional hypermetria: The same (negative) displacement is obtained with the left and the right hands. One would accordingly have to say that MF showed left to right directional hypermetria but right to left directional hypometria. This analysis would be superficially "correct" but is clearly of no explanatory significance.

Nonetheless, the distinction between tasks with and without physically present visual targets seems crucial to understanding MF's performance. It seems plausible to assume that MF (due to her predominantly posterior right hemisphere lesion) has an impairment in attending to left space. She accordingly shows perceptual/attentional left neglect on complex tasks with distractors, such as star cancellation. When drawing (spontaneously) or copying, her reproduction of the right side of the object (see Fig. 1) in itself constitutes a "distraction" from the left (i.e., she cannot "disengage" from what she is doing on the right). This perceptual/attentional neglect is, however, *relatively* unstable. On simpler tasks (line cancellation, without distractors, and the landmark test, without a manual response) MF performs well. Furthermore, when explicit targets are present (all cancellation tasks),

MF can correctly direct a manual response to any target to which she has attended. There is no optic ataxia: MF never fails to hit a physical target at which she is aiming. The limited data we collected also suggest that she can hit a remembered target (see case description). This further refines our interpretation: the crucial aspect of line bisection seems to involve spatial computation without a visible target present in advance (either physically present or represented in visuospatial working memory).

This pattern of perceptual/attentional left neglect contrasts with MF's performance on line bisection. Here we conjecture that the damaged right posterior hemisphere "spatial map" can no longer adequately control (inhibit) the premotor computation of how the hand should be programmed to "reach" an "imaginary" (internally computed) target. Our data do not allow us to decide exactly where in the translation among perceptual, premotor, and motor aspects of the line bisection task the problem is primarily located. We also conjecture that following this disconnection from control of right posterior regions, right frontal areas in MF become hyperactive. Thus, when no *physical* target is present to aim at, motor performance is "skewed" leftward by the (qualitatively) normal bias (Kinsbourne, 1993) of the right hemisphere. When bisection is performed with the left hand, that hand accordingly undershoots the "imaginary" target with left start.

The "hyperactivity" of right frontal regions must be sufficiently strong to override the "natural" (rightward) bias of left frontal regions, as the same pattern of overshoot with right start and undershoot with left start is found when MF bisects with the right hand. A similar conjecture has been advanced by Kwon and Heilman (1991) to explain the performance of a patient who, after a right cerebral infarct, showed left neglect on line bisection on day 1, but right neglect on day 5. They too speculated that the anomalous performance on day 5 was due to hyperactivity in (parts of) the lesioned hemisphere. Direct evidence that such a phenomenon is possible comes from a PET study by Heilman et al. (1990). The patient, after a retrosplenial lesion, showed left frontal hyperactivity, associated with a strong propensity to direct attention to the right.

In our case (MF), the premotor nature of the impairment on line bisection (right neglect) is evidenced by the results of Experiments 6 and 7 (in which the directional deficit is finally overcome). In Experiment 7, there *are* targets: The *ends* of a line are *physical* targets. We accordingly conjecture that directing a motor response to the ends of a line immediately prior to bisection enables MF to "calibrate" her motor system. This calibration, which involves proprioceptive feedback of the kinetic variables required to reach the end points then enables her to locate the "imaginary" target (midpoint), the perceptual position of which we know she can recognize (Landmark test) with good accuracy. Her *relatively* good performance on the landmark test might be thought strange in a patient with a right parietal lesion. We note, however, that the Landmark test differs from bisection by virtue of con-

taining a physical target. Furthermore, there is only one target per trial (in contrast to cancellation tasks). Such a target accordingly acts as an attentional cue. Interestingly, a similar result was reported by Werth (1993) in the case of Patient 1, who also transected lines to the left of center. When Werth required this patient to point with her finger to each end before bisection she now performed correctly. Likewise, the presence of smaller lines (18 mm) in Experiment 6 enables MF to calibrate her reach: We know that she can "hit" a small target (her motor response never "misses" the target in line, letter, or star cancellation). We accordingly conjecture that "hitting" an 18-mm line calibrates the premotor system to (at least)  $\pm 9$  mm in a bisection task. That error ( $\pm 9$  mm) is approximately her mean error on 180-mm lines in Experiment 6 and contrasts sharply with errors of  $-20$ ,  $30$ , or  $40$  mm when 180-mm lines are bisected in isolation. In short, then, MF shows (as expected) left perceptuo-attentional neglect on cancellation, but right premotor neglect on bisection in circumstances when the motor system cannot be adequately calibrated to the perceptual system. It is possible that much the same explanation might apply to three similar cases reported by Robertson et al. (1994), but in whom the reliability of the phenomenon was not established. The case (RH) reported by Marshall and Halligan (1996) may also be explicable within this same framework, although the directional dissociation found in RH was manifest only as a contrast between the performance of the left and the right hand.

Current accounts of visuospatial neglect have stressed that the two cerebral hemispheres have opposing orientational biases (Kinsbourne, 1993) and different predispositions to attend locally or globally (Halligan & Marshall, 1994). Yet neither characterization of *hemispheric* specialization will suffice to account for bidirectional neglect on two tasks that fall within the same domain of nonverbal visuospatial processing. Our putative explanation of MF's performance has accordingly emphasized the notion of reciprocal inhibition and excitation between anterior and posterior regions within the right hemisphere (Denny-Brown & Chambers, 1958). The notion of "transcortical release" that Denny-Brown & Chambers discuss should perhaps receive greater attention in future accounts of bidirectional neglect and other seeming anomalies of the attentional system. We are accustomed to describing the lateralized impairments due to hemispheric imbalance as (left or right) neglect. Whether lateralized impairments due to within-hemisphere imbalances should also be called "neglect" is perhaps a nonquestion. All we have attempted to show is that the interpretation of MF's performance seems to require reference to both between- and within-hemisphere disequilibrium. It remains to be seen whether other examples of bidirectional impairment, such as the dissociation between left neglect on cancellation and right neglect on tactile exploration after right hemisphere damage (Villardita, 1987), also implicates intrahemispheric imbalance.



## APPENDIX

EP is a 72-year-old right-handed woman with a history of high blood pressure who was admitted to hospital on March 28, 1991, with a left hemisphere stroke. On examination, she showed a dense hemiplegia of the right leg and arm; severe sensory loss of the right side, including the arm, leg, and face; and a mild expressive dysphasia. There was no visual field deficit, although she showed florid extinction of stimuli on the right in both the visual and tactile modalities. A CT scan (March 29) showed areas of low attenuation in the posterior limb of the left internal capsule and lentiform nucleus consistent with an infarct. Initial neuropsychological testing was begun on April 14, 1991. Examined on the Behavioural Inattention Test (Halligan et al., 1991) and using her left hand, EP obtained a score of 114/146. On all the cancellation, drawing, and copying tests from the BIT, EP showed *right* neglect: Where omissions occurred, all were on the right. Although right neglect after left hemisphere lesion is comparatively rare, well-documented cases have been reported previously (Caramazza & Hillis, 1990; Cubelli et al., 1991; Humphreys & Riddoch, 1994).

The only peculiarity of EP's performance was on line bisection, where she reliably showed *left* neglect. Over the next 3 years, EP made a slow recovery from her stroke, although no formal assessments of her neglect took place during this period. Her medical notes during this time indicated that motor functioning improved more in her leg than in her arm. However, her most persisting and severe problem continued to be right neglect. This affected many everyday abilities: washing, makeup, dressing, and eating food. She also tended to ignore objects and people on her right side, which on occasion led to accidents. When we tested her again on March 3, 1994 (3 years later), she still had difficulty moving her right arm and leg, although she could now hold and move a pen in the right hand.

### *Experiment A*

Star cancellation from the BIT was administered on the two occasions we assessed EP (1991 and 1994). The task requires the patient to search for and cross out 54 small stars among several different types of foils. In all instances, the A4 stimulus sheet was presented on the desktop and centered on the patient's midsagittal plane. EP performed the task with her left hand. No time limit was imposed and the patient was requested to put down the pen when she was satisfied that all targets had been cancelled.

On both testing occasions, EP's performance was outside normal limits. On the first assessment (1991), EP scored 44/54 and showed only contralesional neglect—all the 10 stars omitted were located in the two rightmost columns. Three years later, she scored 45/54, again with all 9 stars omitted from the two rightmost columns.

### *Experiment B*

Horizontal line bisection tasks were carried out twice (1991 and 1994). On each occasion EP bisected 10 black 180-mm lines (1 mm in width) with her left hand and starting at the left side of each line. As before, transection accuracy was measured to the nearest millimeter and expressed as positive (+) for rightward and negative (−) for leftward displacements.

On standard line bisection, EP produced a significant displacement of her transections to the right on both occasions. The magnitude of this left neglect was reliably outside the normal limits of  $-7.2/+4.3$  for right-handed subjects using their left hand (Irving Bell, 1993; Scarisbrick et al., 1987). The results of both the cancellation and the bisection tasks are summarized in Table A.

TABLE A  
The Results of EP's Bisection and Cancellation Performance Carried Out  
in 1991 and 1994

Line bisection	Deviation	Cancellation (number of omissions)	
		Left	Right
First assessment (10 × 180 mm) (LH/LS)	+14.5 (10.8)	0	10
Second assessment (10 × 180 mm) (LH/LS)	+16.7 (5.8)	0	9

### Experiment C

This experiment was identical to Experiment 6 performed by MF: the patient was required to bisect lines (1 mm in width) that varied from 18 to 180 mm in steps of 18 mm. This version of line bisection was performed at the second assessment only in 1994. As before, each line was presented individually and centered horizontally and vertically on a sheet of white A4 paper. All line lengths were presented 10 times, with order of presentation pseudo-randomized across lengths. The results are shown in Table B.

The linear regression equation for the displacement of transections and standard deviations on line length (with the proportion of variance accounted for) was: signed mean deviation,  $y = -1.84 + 0.098x$  line length (35%); SD,  $y = 2.15 + 0.0565x$  line length (83%). With respect to signed displacements, both the intercept (-1.84) and the multiplier (+0.098) are outside normal limits (Manning et al., 1990). Unlike the case of MF, the magnitude of EP's (left) neglect on line bisection (at 180 mm) is not reduced by giving lines of differing lengths in random order.

TABLE B  
EP's Bisection Performance Using Randomized  
Line Lengths That Varied between 18 and  
180 mm

Line length (mm)	Signed deviation	Absolute deviation
180	14.5 (10.8)	14.9 (10.2)
162	11.1 (11.1)	11.5 (10.9)
144	5.2 (10.5)	8.4 (7.8)
126	17.1 (9.5)	17.1 (9.5)
108	6.4 (11.2)	11.4 (5.1)
90	14.9 (8.1)	14.9 (8.1)
72	13.9 (4.1)	13.9 (4.1)
54	11.8 (5.9)	11.8 (5.9)
36	-10.6 (3.8)	10.6 (3.8)
18	-4.8 (2.5)	4.8 (2.5)

We report these (very limited) data on EP to indicate that the bidirectional task-specific neglect seen in MF is not a peculiarity solely of one patient. In the case of EP, it would likewise appear that unilateral lesion (in this instance of the left hemisphere) can provoke lateralized impairments on both cancellation and bisection, albeit with a changed direction of neglect between the two tasks. Our theoretical interpretation of EP's performance is closely similar to that we have proposed for MF. The main difference is simply that we must regard EP as manifesting (prior to her stroke) reversed hemispheric dominance for spatial cognition. In this sense, all cases of longstanding right neglect after unilateral left hemisphere damage are analogous to those similarly rare patients who show dysphasia after unilateral right hemisphere damage.

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