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# Laterally directed arm movements and right unilateral neglect after left hemisphere damage

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**Abstract**

Signs of unilateral neglect for events occurring in one hemispace most often result from right hemisphere lesions. Right unilateral neglect after left hemisphere damage is much rarer, and has received less attention. The present study explores the relationships between right unilateral neglect and asymmetries in producing laterally directed arm movements in the horizontal plane in left brain-damaged (LBD) patients. Participants produced right- or left-directed arm movements with their left arm in response to centrally located visual stimuli. Results showed that LBD patients with signs of right unilateral neglect were consistently slowed when producing arm movements toward the right (neglected) side, as compared to left-directed movements. Taking into account patients with and without signs of neglect, this directional asymmetry positively correlated with a reaction-time measure of perceptual spatial bias. These findings stand in contrast with previous results obtained with the same experimental paradigm in right brain-damaged patients, in whom a consistent slowing of leftward-directed movements was rare and apparently unrelated to the presence and severity of left neglect. These conflicting results are discussed with respect to the hypothesis that different mechanisms may underlie left and right unilateral neglect. 

*Keywords:* Unilateral neglect; Directional hypokinesia; Reaction time; Brain damage

## 1. Introduction

Patients with unilateral brain damage may show slowed or hypometric arm movements toward the contralesional space, as compared to movements directed towards the side of the brain lesion [20,25,28]. Mattingley et al. [25] proposed to label 'directional hypokinesia' the slowing in movement initiation, and 'directional bradykinesia' the slowing of movement time. That these phenomena are related to the side of space, rather than to the side of the body, is shown by the fact that they are apparent even when patients perform movements with their ipsilesional (unaffected) arm.

Directional motor disorders were originally thought to be a part of the syndrome of left unilateral neglect [20,29]. As a consequence, the great majority of the studies on this topic have been conducted on right brain-damaged (RBD) patients. Recent evidence, however, indicates that, in left neglect, hand or arm movements toward the left side are often normal, if not hypermetric, in amplitude [9,19,21,22,30,33]. Also the time to produce these arm movements may show no leftward/rightward asymmetry, except perhaps in a minority of neglect patients, who do show directional hypokinesia [6]. In this latter study, 34 RBD patients performed an RT paradigm requiring lateralized arm responses to central vertical stimuli, similar to a traffic light. Results showed that left neglect patients were less accurate for left-directed than for right-directed re-

*Abbreviations:* LBD – Left brain-damaged; RBD – Right brain-damaged; RT – Reaction time.

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sponses; however, their speed in producing left-directed movements was comparable to that for rightward movements. Indeed, accuracy of performance, but not RTs, correlated with results on the neglect test battery and with asymmetrical performance on another RT test, requiring central responses to lateralized targets. Only two RBD patients (showing no signs of severe neglect) were consistently slowed in producing leftward motor responses. The observed dissociation between accuracy and speed was accounted for by proposing that neglect patients were impaired in perceptually coding the left-sided response site; however, leftward movements per se were normal for most patients, as shown by RTs in those trials in which the left-sided landing area was correctly reached. While these results still left open the possibility that a directional motor disorder may contribute to left neglect signs in some instances, they clearly also made the case for a double dissociation between left neglect and directional bias in executing arm movements. Consistent with this interpretation, Mattingley et al. [26] found that leftward movements were slowed in neglect patients only in the following conditions: (1) when the movement path could not be predicted in advance (thus necessitating a perceptual selection among different candidates to reach for), and (2) in the presence of a concurrent right distractor (which presumably attracted neglect patients' attention; [14,17,24])[1].

The finding that directional motor disorders only rarely co-occur with left neglect in RBD patients prompts the question about its frequency of occurrence in left brain-damaged (LBD) patients. Although there is general agreement that unilateral neglect is much less frequent, severe and persistent in LBD than in RBD patients (but see [32]), signs of spatial bias favouring the left hemispace may emerge in LBD patients. The proposal has been advanced that right neglect might differ from left neglect not only quantitatively, but also qualitatively [18]. The study of LBD patients' performance on neglect tests and on tasks exploring directional arm movements might thus disclose patterns of impairment different from those shown by RBD patients.

[1] In a further study, Mattingley et al. [27] asked left neglect patients with right parietal or frontal lesions to reach for lights appearing right or left of fixation with their hand starting at the body midline (i.e., between the targets) or left or right of both targets. Parietal patients showed a deficit in initiating leftward reaches. However, when the hand started form the extreme right position, left targets again evoked slower responses than right targets (which also required a leftward movement in this condition), indicating that the impairment did not concern leftward movements per se, but only leftward movements directed to left-sided targets. Thus, these results cannot be unequivocally interpreted as demonstrating directional hypokinesia.

In the present study, we used an RT task requiring lateralized responses to centrally presented stimuli (the traffic light paradigm [6]), in order to explore the speed and accuracy of laterally-directed arm movements in a series of 28 LBD patients, who also underwent a test battery evaluating unilateral neglect. Performance on the traffic light paradigm was contrasted with that on a 'perceptual' RT task, with similar but horizontally arranged visual stimuli and central motor response (press the computer space bar). This task, when used in RBD patients, has proved sensitive enough to disclose forms of spatial bias not evident on paper-and-pencil testing [1–3].

## 2. Methods

### *2.1. Subjects*

A total of 28 patients with unilateral lesions in the left hemisphere (mean age 54.29 yr, range 29–88) and ten age-matched control participants free of neurological damage (mean age 54.40 yr, range 23–76) consented to participate in this study. Three further LBD patients were excluded from the present series because they could complete only one of the two conditions of the traffic light paradigm (see below). Patients were consecutively enrolled, provided that their verbal comprehension was sufficient to understand the task instructions. All participants were right-handed, except for patient 6, a left-handed woman who had been educated to use her right hand as preferred hand. No patient showed signs of optic ataxia on clinical examination. Table 1 reports patients' demographical and clinical data.

Unilateral neglect was assessed using a battery of visuospatial tests [3], which included tasks of line, letter, and bell cancellation, identification of overlapping figures, copy of a landscape and line bisection. All patients performed the tests with their left, unaffected hand. On the basis of their performance on the neglect battery, three patients were considered as showing signs of right unilateral neglect (patients 1–3 in Table 1), a figure comparable to the frequency of right neglect assessed with a similar battery in a different series of LBD patients [5]. The performance of these three patients on the neglect battery is reported in Table 2.

Patient 1 omitted right-sided items on cancellation, copy and figure identification tasks. She had right hemianopia on confrontation task. Patient 2 also made contralesional omissions on cancellation tasks and had right hemianopia. Patient 3 performed symmetrically on cancellation and copy tests, but had a massive (18%) leftward deviation on line bisection, more than 4 SDs from controls' performance on the same test [5]. She had intact visual fields.

Table 1
Demographical and clinical data for LBD patients[a]

| Patient | Sex, age, years of schooling | Days from disease onset | Aetiology | Lesion location | Visual field | Right visual extinctions |
|---|---|---|---|---|---|---|
| 1 | M, 65, 5 | 180 | Hemorrhagic | FTP | H | – |
| 3 | M, 57, 8 | 65 | Ischemic | FTP | H | – |
| 2 | F, 77, 5 | 32 | Ischemic | CR | Normal | No |
| 4 | F, 57, 5 | 731 | Hemorrhagic | F | Normal | No |
| 5 | F, 29, 7 | 922 | Ischemic | FTPO | IQ | Yes |
| 6 | F, 81, 5 | 36 | Hemorrhagic | IC–Th | Normal | Yes |
| 7 | M, 57, 15 | 702 | Ischemic | FP–IC | Normal | No |
| 8 | M, 40, 7 | 539 | Hemorrhagic | F | Normal | No |
| 9 | M, 69, 19 | 277 | Ischemic | P | Normal | Yes |
| 10 | M, 25, 15 | 402 | Ischemic | FT | Normal | No |
| 11 | M, 39, 12 | 217 | Hemorrhagic | FTP | Normal | No |
| 12 | M, 47, 15 | 120 | Hemorrhagic | P | Normal | No |
| 13 | F, 74, 12 | 53 | Hemorrhagic | T | Normal | No |
| 14 | M, 52, 14 | 150 | Hemorrhagic | IC–BG | H | – |
| 15 | M, 78, 10 | 7 | Ischemic | P | Normal | Yes |
| 16 | F, 45, 8 | 132 | Ischemic | F | Normal | No |
| 17 | M, 88, 16 | 242 | Ischemic | F | Normal | Yes |
| 18 | F, 59, 14 | 56 | Ischemic | TP | Normal | No |
| 19 | F, 28, 16 | 930 | Ischemic | TP | Normal | No |
| 20 | M, 28, 15 | 128 | Ischemic | FTP | Normal | Yes |
| 21 | M, 42, 8 | 14 | Hemorrhagic | P | Normal | No |
| 22 | M, 38, 17 | 14 | Hemorrhagic | F | Normal | No |
| 23 | M, 45, 12 | 2517 | Ischemic +hemorrhagic | BG–CI–P | Normal | Yes |
| 24 | M, 43, 9 | 644 | Hemorrhagic | BG–CR | H | – |
| 25 | M, 72, 19 | 36 | Ischemic | F | Normal | No |
| 26 | M, 64, 5 | 430 | Ischemic | FTP | IQ | No |
| 27 | M, 62, 15 | 122 | Hemorrhagic | F | Normal | No |
| 28 | F, 59, 9 | 112 | Hemorrhagic | BG–TP | H | – |

[a] F – frontal; T – temporal, P – parietal; O – occipital; Th – thalamic; IC – internal capsule; BG – basal ganglia; CR – corona radiata; IQ – inferior right quadrantanopia; SQ – superior right quadrantanopia; H – right hemianopia.

## 2.2. Apparatus and procedure

### 2.2.1. Traffic light paradigm

Following a previously described procedure [6], participants sat in front of a computer monitor at a distance of approximately 50 cm. A paper board was placed on the computer keyboard, leaving three windows open on three different positions: a left-sided area (keys q, w, e, a, s, d of the American keyboard), a middle area (keys i, o, p, k, l, ;), and a right-sided area (keys 7, 8, 9, 4, 5, 6 of the numeric keypad). Left- and right-sided areas were about 13 cm distant from the middle area. Three black disks, each 13 mm in diameter, were presented on a white background, arranged in a vertical array at the midsection of the screen, similar to a traffic light. The distance between disks was 23 mm. After an interval of 2000 ms, one of the disks became grey (target). Upon the appearance of an upper target, participants had to move their hand from the home position at the centre of the keyboard to whatever key was situated in a lateral (e.g., left-sided) area, at a distance of about 16 cm from home position. All participants used their left hand to perform the task. When a middle target appeared, response keys were in the middle area, about 10 cm from the home position; when a lower target occurred, participants had to press a key on the other lateral (e.g., right-sided) area, at about 16 cm from home position. The target disappeared when a response was made or after 5000 ms. After every trial, participants had to again place their hand at the home position. Response time was measured from target onset to key press. One block of twelve practice trials and ten blocks of four upper-, four middle-, and four lower-target trials each were presented. The order of trials within a block was randomized. A typical experimental session began with the RT task. Afterwards, other tests were administered (e.g., the paper-and-pencil visuospatial tests). At the end of the session, an inverted version of the RT task was performed (e.g., upper target → right-sided response, lower target → left-sided response). Eleven control participants and 14 patients performed the 'up/left' condition first, the remaining participants performed the task in the opposite order.

Table 2
Performance (left/right correct responses) of right neglect patients on the neglect battery[a]

| Patient | Line cancellation (max 30/30) | Letter cancellation (max 30/30) | Bell cancellation (max 15/15) | Landscape drawing (max 3/3) | Overlapping figures (max 10/10) | Line bisection (% leftward deviation) |
|---|---|---|---|---|---|---|
| 1 | 30/29 | 22/16 | 13/7 | 3/1 | 10/9 | 7 |
| 2 | 29/26 | 15/7 | 12/8 | 3/3 | 10/10 | 1 |
| 3 | 30/30 | 30/30 | 15/15 | 3/3 | 10/10 | 18 |

[a] The landscape drawing (a house with two trees on each side [18]) was evaluated by assigning 1 point to each item completely copied, except for the house, which was assigned 2 points, one for its left half and one for its right half.

Only correct lateralized responses, i.e., responses directed to the left- or the right-sided area, were taken into account in the RT analysis. All responses with RTs either less than 150 ms or more than 4500 ms were discarded from analysis.

### 2.2.2. 'Perceptual' RT task

In this task [1], three horizontally arranged black disks were displayed on a white background, the central disk being located at the centre of the screen. After an interval randomly chosen from the set 1000, 1300, 1700 or 2000 ms, either the right-sided or the left-sided disk became grey. As soon as the target appeared, participants had to respond by pressing the spacebar as quickly as possible. Response time was measured from target onset to key press. The target disappeared when a response was made or after 5000 ms. One block of six practice trials and ten blocks of four right- and four left-sided trials each were presented. The order of trials within a block was randomized. Only responses that fell in the range of 150–4500 ms were taken into account in the RT analysis.

## 3. Results

### 3.1. Traffic light paradigm

Fig. 1 shows participants' performance on the traffic light paradigm.

Separate repeated-measures analyses of variance (ANOVAs) were conducted for accuracy and response times, with group (control, LBD without neglect, LBD with neglect) and order of performance (up/left first, up/right first) as between-subject factors and response site (left, right) and task condition (up/left, up/right) as within-subject factors. The $p$ values were corrected using the Geisser–Greenhouse correction to take into account possible violations of the sphericity assumption. In addition, statistical power was calculated for each main effect or interaction. A power value of around 0.80 can be considered reasonable for behavioural sciences [23]. Theoretically relevant results were followed up by paired comparisons.

The ANOVA conducted on the accuracy rates revealed an effect of group, $F(2, 32) = 17.42$, $P < 0.0001$, power = 1.00, because right neglect patients made more errors (33.5%) than patients without neglect (8%), $F(1) = 33.02$, $P < 0.0001$ or normal controls (2.5%), $F(1) = 34.55$, $P < 0.0001$. An effect of the task condition was also present $F(1, 32) = 14.53$, $P < 0.001$, power = 0.97. This effect interacted with the group, $F(2, 32) = 8.64$, $P < 0.005$, power = 0.96, because neglect patients made more errors (47%) in the up/right than in the up/left condition (20%), whereas the other groups performed comparably on the two conditions, a result for which we have no interpretation to offer. This pattern of errors concerned two of the three neglect patients, and did not apparently depend on the order of conditions, because one patient performed the up/right condition first, and the other second. Also significant, but with a lesser statistical power, was the interaction between condition and order of performance, $F(1, 32) = 7.03$, $P < 0.05$, power = 0.74, because when participants performed the up/left condition first, they tended to make fewer errors (4.9%) than in the other situations (up/left condition performed as second task, 9.5%; up/right as first, 9.4%; up/right as second, 10.4%). No other effect or interaction was significant. In particular, neither the effect of side, nor the group/side interaction were significant (both $F < 1$), suggesting that participants responded with comparable accuracy on the two sides of the keyboard.

Also the ANOVA conducted on RTs revealed a significant difference between groups, $F(2, 32) = 11.18$, $P < 0.0005$, power = 0.99, because LBD patients with neglect had slower RTs (2193 ms) than both patients without neglect (1447 ms), $F(1) = 6.06$, $P < 0.05$, and controls (852 ms), $F(1) = 17.99$, $P < 0.0005$. Patients without neglect were also slower than controls, $F(1) = 12.78$, $P < 0.005$. Neither the stimulus-response arrangement, nor the order of performance of the two conditions had any effect on performance, $Fs(1, 32) < 1.83$, but these factors interacted, $F(1, 32) = 4.18$,

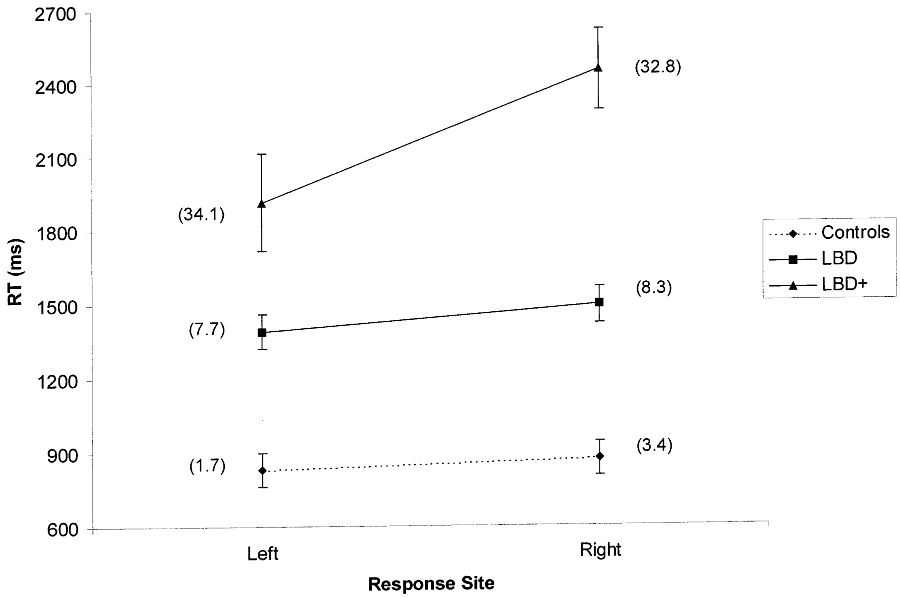



Fig. 1. Response times (RTs) for control participants and LBD patients with (LBD + ) or without (LBD) right-sided neglect on the traffic light paradigm. Error bars indicate the s.e.m. The percentage of errors is reported in parentheses.

$P<0.05$, power $=0.50$, as if each task condition elicited faster responses when it was performed as first task than when it was performed as second task. The low statistical power of the test does not, however, allow strong conclusions on this effect.

Importantly, there was an effect of the side of response, $F(1, 32)=39.90$, $P<0.0001$, power $=1.00$, which interacted with the subject group, $F(2, 32)=10.46$, $P<0.0005$, power $=0.99$. As is evident from Fig. 1, this interaction resulted from neglect patients being 552 ms (or 29%) slower to produce right-directed responses than left-directed responses, whereas LBD patients without neglect and controls showed a much less marked right-left difference (patients: 104 ms, or 7%, controls: 41 ms, or 5%). The group by side interaction was still present when the data from the control group were eliminated, $F(1, 24)=13.41$, $P<0.005$, power $=0.96$, thus confirming that it did originate from neglect patients' asymmetry of performance. Three further interactions concerning the side of response proved significant. Side interacted with the task condition, $F(1, 32)=15.35$, $P<0.0005$, power $=0.98$, and with task condition and group, $F(2, 32)=5.06$, $P<0.05$, power $=0.79$, because in the neglect group the left-right RT asymmetry was larger in the up/left than in the up/right condition. Also the order of performance interacted with the side, $F(1, 32)=7.58$, $P<0.01$, power $=0.77$, because the left/right RT asymmetry was larger when the up/right condition was performed first. These last effects are difficult to interpret; their reliability is, however, doubtful, given the relatively low statistical power of the tests.

### 3.2. 'Perceptual' RT task

Performance on this task is shown in Fig. 2.

Separate ANOVAs were performed on error rates and RTs, with group (control, LBD without neglect, LBD with neglect) as between factor and target side (left, right) as within factor. The error rates were low in this easy task, and not significantly different among the three experimental groups ($F<1$), but they were influenced by the target side, $F(1, 35)=6.53$, $P<0.05$, power $=0.70$, which interacted with the group, $F(2, 35)=3.33$, $P<0.05$, power $=0.59$. Neglect patients tended to make more errors for right targets than for left targets, whereas the other groups showed no such asymmetry (Fig. 2). Note, however, that these effects concerning accuracy of response were small, as expected by the undemanding nature of the task, and relatively unreliable, as shown by the low statistical power of the tests.

The ANOVA performed on RTs revealed an effect of the group, $F(2, 35)=11.62$, $P<0.0001$, power $=0.99$, because neglect patients were slower than both controls, $F(1)=23.15$, $P<0.0001$, and patients without neglect, $F(1)=17.21$, $P<0.0005$. There was also an effect of side, $F(1, 35)=7.90$, $P<0.01$, power 0.79, which interacted with the group, $F(2, 35)=4.44$, $P<0.05$, power $=0.73$, because patients had longer RTs for right targets than for left targets, an asymmetry which was absent in controls (Fig. 2). The group/side interaction was still marginally significant after excluding the control group, $F(1, 26)=4.05$, $P=0.0546$, power 0.48, thus suggesting that the perceptual RT task elicited a

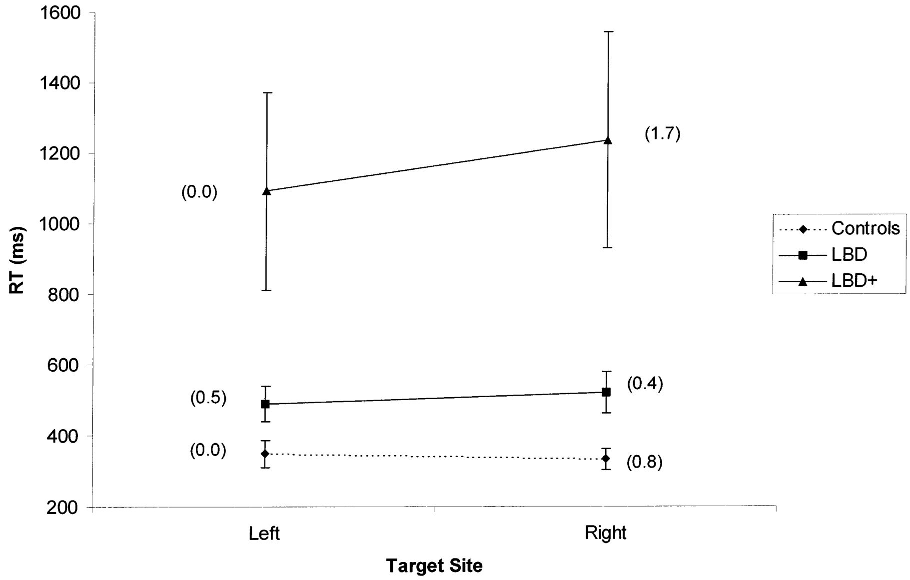



Fig. 2. Response times (RTs) for control participants and LBD patients with (LBD+) or without (LBD) right-sided neglect on the 'perceptual' RT task. Error bars indicate the s.e.m. The percentage of errors is reported in parentheses.

stronger RT asymmetry in the neglect than in the non-neglect patient group. The low power of the test suggests, however, that this effect is relatively unreliable.

To investigate the relationship between perceptual and motor spatial biases in LBD patients, we computed the correlation coefficient between laterality scores ((RT left − RT right)/(RT left + RT right)) obtained in the perceptual RT task and in the traffic light paradigm (for which RTs for the two task conditions were pooled together)[2]. Laterality scores positively correlated with each other, $r = 0.49$, $z = 2.65$, $P < 0.01$.

### 3.3. Comparison with RBD patients' performance

Thus far, the present results seem in striking contrast with those obtained with the same paradigm in previous studies on RBD patients [3,6], where leftward hypokinesia was found to be relatively independent of signs of perceptual spatial bias. To compare the present results more directly with RBD patients' performance, we plotted the response times obtained by RBD patients and normal controls performing the traffic light paradigm with their right hand [6] together with the present data.

As Fig. 3(A) shows, the group of LBD patients with right neglect demonstrated the largest asymmetry between movements directed toward the side contralateral to the hand used and ipsilaterally directed reaches. This is even more evident when the data are plotted in terms of laterality scores (obtained as described in the previous paragraph) (Fig. 3(B)). An ANOVA conducted on these scores with the subject group as factor demonstrated a significant group effect, $F(5, 80) = 18.55$, $P < 0.005$, power 0.92. Paired comparisons (Fisher's PLSD) showed that this effect resulted exclusively from the performance of LBD patients with right neglect, all $P\text{s} < 0.0005$.

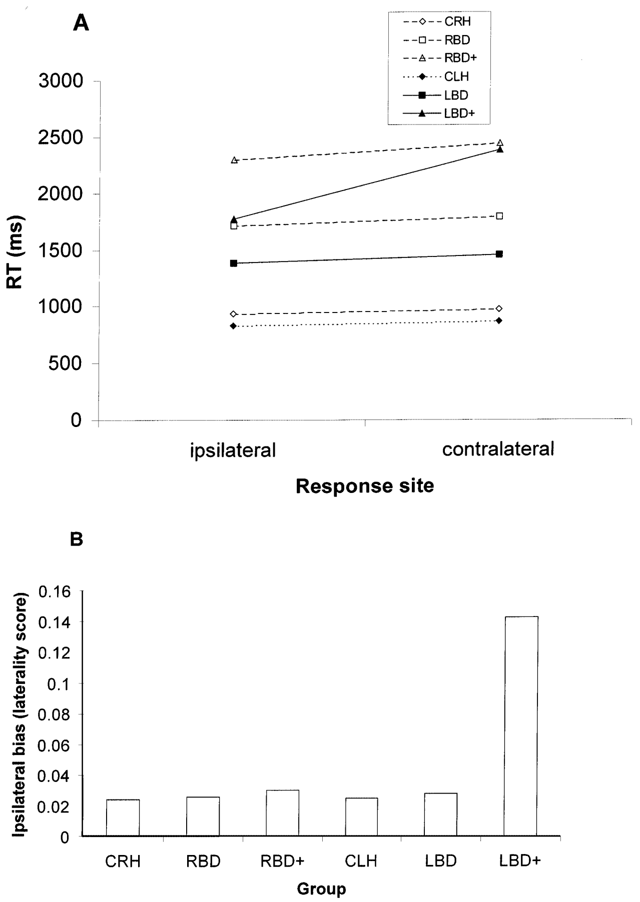
It was more difficult to compare RBD and LBD patients' performance on the perceptual RT task, because for RBD patients this task included catch trials (which generally increase RTs to imperative stimuli), whereas in the present study there were no catch trials. We decided to eliminate catch trials because recent data suggested that the presence of catch trials increases the spatial bias in RBD patients without signs of neglect (perhaps by interfering with compensatory mechanisms [2]). To minimize these problems in comparing data from RBD and LBD patients, we restricted the comparison to right and left neglect patients (whose spatial bias was apparently unaffected by catch trials in the above mentioned study [2]), and employed laterality scores to evaluate asymmetry of performance independent of the general increase of RTs caused by catch trials. These data are reported in Fig. 4.

An ANOVA performed on laterality scores with group (RBD, LBD) as between-subject factor and task (motor, perceptual) as within-subject factor showed no main effect of group or task ($F < 0$), but a significant interaction between these two factors, $F(1, 14) = 8.07$, $P < 0.05$, power 0.76. As is evident from Fig. 4, this interaction resulted from right neglect patients showing more ipsilateral bias in the motor than in the perceptual task, whereas the opposite was true for left neglect patients.

[2] Correlation coefficients with paper-and-pencil neglect tests were not calculated because only the three neglect patients showed asymmetrical performance on these tests.

## 4. Discussion

We employed the traffic light paradigm, a RT task with central visual stimuli and lateralized arm responses, to explore the speed and accuracy of directional arm movements in LBD patients, and their relationship with signs of bias favouring the left side of space. Our results indicate a consistent association in LBD patients between slowed right-directed responses and perceptual spatial bias, as assessed either by a neglect paper-and-pencil battery or by a 'perceptual' RT task, consisting of lateralized visual stimuli and central motor responses. Our findings confirmed that also normal individuals' arm movements are slowed when directed toward the side contralateral to the arm employed [15]. However, the RT difference that we found in right neglect patients was much larger than expected from this physiological asymmetry, as demonstrated by the highly significant side-by-group interaction. Despite the low number of right neglect patients in our sample, due to the relative rarity of this disorder, their slowing in producing right-directed movements is statistically robust, as shown by the adequate power of the relevant statistical tests. Further, more fine-grained research is needed to ascertain whether the slowing of contralesionally directed movements in right neglect patients, if confirmed, results from an increased latency to initiate the movement toward right targets, or whether it rather reflects an increased movement time [16].




CRH, controls using their right hand; RBD, right brain-damaged patients without signs of neglect; RBD+, right brain-damaged patients with left neglect [data from Ref. 6]; CLH, controls using their left hand; LBD, left brain-damaged patients without neglect; LBD+, left brain-damaged patients with right neglect

Fig. 3. (A) Performance on the traffic light paradigm of control subjects and RBD and LBD patients with or without contralesional neglect for response sites ipsilateral and contralateral to the hand used. RBD patients used their right hand [6]. (B) The same data plotted as laterality scores [(ipsilateral RT − contralateral RT)/(ipsilateral RT + contralateral RT)].

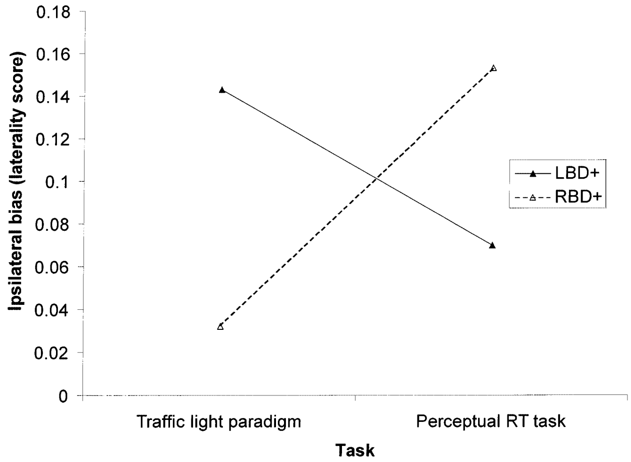



Fig. 4. Performance of LBD and RBD patients [6] with contralesional neglect on the traffic light paradigm and on the perceptual RT paradigm, expressed as laterality scores [(ipsilateral RT − contralateral RT)/(ipsilateral RT + contralateral RT)].

Despite the theoretical interest of the question, directional arm movements have only occasionally been explored in LBD patients. Heilman et al. [20] found that LBD patients without neglect produced left- and right-directed movements with comparable speed. Fisk and Goodale [16] studied visually guided reaching in 17 RBD and 11 LBD patients, and found that RBD patients were slower then controls in initiating movements, whereas LBD patients required a longer time than controls to execute the reach once it had been initiated. Unfortunately, the authors did not explore the influence on directional movements of unilateral neglect, which was present in five RBD and in one LBD patient. Coslett et al. [12] reported a patient with left temporo-parietal and anterior cingulate lesions, who performed worse in the right hemispace than in the left on a variety of motor, language and sensory tasks. However, on a lateral pointing task a better accuracy for left-sided than for right-sided targets was found only for the right hand, and RTs were not evaluated. In a study devoted to visual and tactile exploration of space in brain-damaged patients, De Renzi et al. [13] asked RBD and LBD patients to find a marble in a $50 \times 40$ cm$^2$ maze when blindfolded. RBD patients failed more often than LBD patients to find the marble when it was in the contralesional part of the maze. However, when searching time was considered, both groups of patients were slowed for contralesional, as opposed to ipsilesional, items. Chokron and Bartolomeo [11] asked LBD patients to point straight-ahead with their left (unaffected) arm while blindfolded, starting from different, laterally displaced positions of the arm, and found a positive correlation between right neglect signs and tendency to deviate leftward on this task. This finding concurs with the present results in suggesting a bias of laterally directed movements in right neglect patients, and stands in sharp contrast with performance of RBD patients, in whom no significant correlation emerged between left neglect and performance on pointing straight-ahead [3,4,10].

As is generally the case with findings of an association between different symptoms, our results might simply mean that our right neglect patients suffered functional damage large enough so as to encompass different cognitive systems [35]. Experimental replications could help to rule out this potential problem. Some indirect support to our conclusions comes, however, from the study of Heilman et al. [20], who found no asymmetry of laterally directed movements in seven LBD patients without signs of right neglect. Importantly, our present results stand in striking contrast with the data obtained with similar RT paradigms in RBD patients [3,6]. In these studies, left neglect signs were found to correlate with performance on 'perceptual' RT tasks (lateralized targets, central response), but not with performance on the traffic light paradigm, which only rarely disclosed slowed leftward responses. In particular, left neglect patients showed reduced accuracy for reaching left-sided response sites, thus suggesting a difficulty in the perceptual encoding of these left-sided targets, but for correct responses RTs to attain left targets were symmetrical to those obtained to reach right targets [6]. The accuracy rates, but not the RTs, correlated with neglect tests and the perceptual RT task. In contrast, the LBD patients with right neglect described in the current study made a substantial number of errors for both response sites (perhaps consistent with the notion of a left hemisphere dominance for action selection [34]), but had slowed RTs only for right-sided sites. This RT asymmetry correlated with the perceptual RT task (whose outcome was generally less biased than in left neglect patients, Fig. 4).

These discrepancies between studies on RBD and LBD patients are in broad agreement with the proposal that different mechanisms underlie unilateral neglect after left, as opposed to right, hemispheric damage [18]. One possible, though admittedly speculative, interpretation of these results is that a basic impairment in left neglect might involve a biased exogenous orienting of attention, which favours right-sided over left-sided visual objects in the perceptual apprehension of the visual scene [7,8,14,17]. On the other hand, if the present results were to be confirmed, right neglect might be seen as concerning a bias affecting processing stages more closely related to action, consistent with the notion of a left hemisphere dominance for action selection [34], as well as with the suggestion [31] that right neglect might result from lesions more anterior than those observed in left neglect.

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