Categorisation of ‘perceptual’ and ‘premotor’ neglect patients across different tasks: is there strong evidence for a dichotomy?

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Abstract

The aim of the presented studies was to investigate whether classifications of neglect patients into perceptual (i.e. identifying a patient as suffering from mainly attentional/space representation deficits) and premotor (judging the main impairment to be related towards actions into contralesional space) categories is consistent across different line bisection assessment techniques that have, in the past, been designed to tease these potentially overlapping aspects of hemispatial neglect apart.

Twelve patients with hemispatial neglect and three control groups were tested with the Overhead Task, adapted from Nico [Neuropsychologia 34 (1996) 471] in which patients were asked to bisect lines that were mirror reversed, the Pulley Device Technique, adapted from Bisiach et al. [Neurology 40 (1990) 1278] in which they had to perform a movement opposite to the direction of the transaction mark that bisected the line and the Landmark Test, adapted from Milner et al. [Neuropsychologia 30 (1992) 515] in which they had to manually point to the half of a centrally pre-bisected line that, to them, appeared shorter. The specific question was whether these three tasks would categorise the same set of patients in the same way?

Most patients could be classified into either the premotor or perceptual category in *each task*, but no consistent categorisation emerged *across the three techniques*. Just 1 out of the 12 patients, was consistently classified across all three tasks. It seemed that despite the fact that all tasks essentially required a line bisection response, the perceptual and motor differences between the tasks were still great enough to result in inconsistent classifications. The Landmark Task classified the majority of patients into the perceptual neglect category, while the Overhead and Pulley Device Techniques tended to identify more patients as suffering from a premotor deficit (albeit not the same set of patients). © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Over the past 15 years there has been an increasing recognition that neglect is not a unitary phenomenon, i.e. that there are different types see [27]. According to Heilman and co-workers [16] many patients suffer from ‘directional hypokinesia’, a symptom in which they are reluctant and slow to initiate a movement in the direction contralateral to their brain lesion. Heilman and Valenstein [15] have argued that this symptom could explain both the occurrence and the nature of the rightward error that neglect patients typically show when asked to bisect a line in the centre [3,12,31,34]. However, Bisiach et al. [4] realised that in any test of line

bisection ‘premotor’ and ‘perceptual’ biases are confounded so that a patient might bisect a line to the right of centre because of a failure to direct the action (directional hypokinesia) and/or because of an attentional failure. In their study, the authors pitted these two factors directly against each other by asking their participants to position a pointer in the centre of a line either directly (congruent condition) or indirectly (incongruent condition) so that positioning the pointer in one direction actually required a movement in the *opposite* direction. As expected their patients bisected consistently to the right when moving the pointer directly. However, patients varied considerably in the extent to which there was still a rightward error when a leftward movement had to occur. This reduction in the bisection error could be taken as an index of the premotor bias that contributed to the line bisection error in the first place.

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Tegnér and Levander [35] published a similar experiment, using a line cancellation task which patients were asked to perform under mirror-viewing and normal conditions. In the mirror condition, 10 out of the 18 patients tested continued to delete stimuli on the visual right only (motoric left), their behaviour seemingly controlled by the perceptual field rather than a premotor bias. Four patients, however, cancelled lines on the right only (their visual left), a behaviour pattern compatible with premotor neglect.

Nico [32] published a study in which Tegnér and Levander's technique and a line cancellation task performed on an overhead projector were directly compared. One of the problems of the mirror task is that the two halves of the mirror are joined in the midline, a feature which interferes with the presentation of the stimuli and makes it impossible to use with the Line Bisection Task, as it would give the patients an inescapable clue with regard to the true centre of the line presented. Direct comparison of the two techniques was found to produce similar results although interestingly, Nico could not find even one premotor patient among the 22 neglect patients tested.

Milner et al. devised a very simple way of distinguishing between the two broad factors assumed to cause the right line bisection errors [25,26]. They argued that if such errors are due to a perceptual distortion, possibly as the result of an attentional and/or representational failure, then a centrally pre-bisected line (landmark) should appear to the patient to be leftwardly bisected. However, if there is no such distortion but instead a premotor bias to respond rightwardly, then the same task should elicit a predominance of rightward-pointing responses when asked to 'point to the end nearer to the bisection mark'. Harvey et al. [14] found exactly this pattern: out of their eight patients, seven pointed predominantly towards the left in the landmark test, indicating a perceptual bias whereas one patient pointed predominantly towards the right, indicating a premotor bias.

Associated with the investigation of perceptual versus premotor neglect is the debate whether either type can be associated with a distinct lesion location in the brain. Mesulam [23,24] proposed that premotor neglect might be correlated with anterior lesions, whereas more posterior lesions might cause perceptual neglect. This dichotomy has generally been supported in a range of studies [4,6,7,8,9,18,35]. Other studies, however, have produced more ambiguous results [1,14] or even contrary findings [6,21].

The obvious question that now arises is whether the dichotomies reported in these experiments are consistent across the varying techniques. That is, would the patients that were classified as say premotor in Bisiach et al.'s Pulley Device Task [4] because they showed a reduced rightward error in the incongruent condition have also shown this in the line bisection version of Nico et al.'s [32] Overhead Task, and indeed have produced more rightward-pointing biases in Milner and colleagues' [25,26] Landmark Task? Are all these techniques tapping the taxonomic distinction in the same way or are the task demands too heterogeneous

to allow a consistent categorisation across tasks? Numerous studies have already shown that there can be dissociations between line bisection and the line cancellation tasks in neglect patients [1,10,13,19,29]. However, within Line Bisection Tasks, it seems reasonable to expect that a patient should be classified similarly across the varying techniques.

The experiments reported were designed to address exactly this issue. By directly comparing the Pulley Device [4], Overhead [32] and Landmark Tasks [25,26] we hoped to address whether all these different attempts do indeed classify *individual* neglect patients in the same way. Moreover, we wanted to investigate the relationship between lesion location and their association to perceptual and premotor neglect within and across tasks.

2. Methods and materials

2.1. Patients and participants

Twelve right hemisphere-lesioned patients [seven male, five female; ranging in age from 62 to 79 years (mean age = 73.4; S.D. = 4.84)] with hemispatial neglect and three control groups [12 patients with right-hemisphere damage (five men, seven women; age range 54–82 years (mean = 73.3; S.D. = 8.06), 12 patients with left-hemisphere damage (nine male, three female; age range 60–82 years, mean = 69.8; S.D. = 6.34) and 13 healthy volunteers (eight male, five female; age ranging from 63 to 75 years (mean = 70.8; S.D. = 3.6)] were recruited. Only patients who suffered from a unilateral cerebral lesion resulting from a cerebro-vascular accident (CVA), as confirmed by CT report, were recruited into the clinical groups. None of the patients in the two patient control groups showed any current or past evidence of hemispatial neglect, as assessed both through the Behavioural Inattention Test (BIT, [37]) and inspection of the medical records.

Only patients with no prior history of concurrent neurological illness, clinical depression, drug abuse or alcoholism were tested. They were usually approached within 4 months of stroke onset, even though in some cases it was considerably later, usually because the patient in question had been identified late. The healthy participants gave no evidence of neurological disease and were matched to the patient sample by age and education. None of the groups differed significantly from each other with regard to age or years of education, nor did the patient groups differ with respect to the time that had elapsed between the onset of the CVA and the time of testing. The data of the control groups are presented purely for the purpose of comparison but are discussed in Krämer [17]. Clinical details of the neglect patients, including lesion locations, are given in Table 1. All of the neglect patients showed some degree of hemiparesis as did 10 out of the 12 right hemisphere-lesioned control patients and four of these control patients also showed hemianopia as assessed both through the medical records and confrontation testing. All

Table 1
Clinical data of the 12 neglect patients

Patient	Aetiology	Lesion location	Weeks sinceonset	Hemi-anopia
J.C.F.	Infarct	Right fronto-parietal	11	No
E.R.	Infarct	Right fronto-temporal	8	No
R.P.	Haemorrhage	Right frontal	4	Yes
L.C.	Infarct	Right occipital, inferior temperature, basal ganglia	94	Yes
H.J.	Infarct	Right fronto-parietal	5	Yes
K.G.	Haemorrhage	Right parieto-occipital	18	Yes
C.P.	Infarct	Right parietal	13	No
D.S.	Infarct	Right fronto-parieto-temporal	18	No
A.F.	Haemorrhage	Right thalamus	8	No
K.A.	Infarct	Right posterior fronto-temporo-parietal	9	Yes
J.R.	Infarct	Right temporo-parietal	4	No
D.D.	Infarct	Right fronto-parietal	9	Yes

of the left hemisphere-lesioned patients suffered from hemiparesis, whereas only one patient also showed symptoms of hemianopia. The distribution of lesion locations was similar in all three patient groups, with all patients having at least some involvement either of the parietal, frontal, temporal lobe or subcortical structures, with the exception of two neglect patients whose damage also included the occipital lobe. All participants in the study were strongly right-handed.

All patients were tested on a range of Neuropsychological Tests (WAIS-R [36], *Benton Visual Form Discrimination Test* [2], *Very short Minnesota Differential Aphasia Test* [33], *National Adult Reading Test* [30]). Significant differences (one-way ANOVAs) on the WAIS-R sub-tests 'Block Design' and 'Object Assembly' were found between the neglect group and the left hemisphere-lesioned group and the neglect group also performed significantly worse than both left and right hemisphere-lesioned patients in the sub-test 'Picture Completion'. A significant difference between the neglect group and the right and left hemisphere-lesioned patients groups also emerged in the *Benton Visual Form Discrimination Test* [2], with the neglect group performing worse than the control groups. Observing the patients during these tests made it clear that the relatively impaired performance of the neglect group was mainly due to them

ignoring the left-side of the stimulus presentation, choosing only stimuli located on the right-side. As expected, in the *Very Short Minnesota Differential Aphasia Test* [33], left hemisphere-lesioned patients produced a significantly lower score than both other patient groups. The *National Adult Reading Test* [30] was the only test given to the healthy subjects and this group achieved a significantly higher total IQ than the left hemisphere-lesioned group and the neglect patients. However, this difference was certainly due to the presence of aphasia in the left hemisphere-damaged control group and neglect dyslexia in the neglect group. In fact, one patient with severe neglect and three patients with severe aphasia in the left hemisphere-damaged group were completely unable to perform this test. To identify patients with hemispatial neglect, the formal sub-tests of the BIT [37] were given to all patients (total and sub-test scores for each neglect patient are given in Table 2). As expected all of the patients in the control groups attained near perfect scores, performing well above the cut-off score of 129/146.

2.2. Task 1 (Overhead Technique; adapted from Nico [32])

Ten black lines of 200 mm length and 1 mm width were placed horizontally and centrally on one A4 transparency.

Table 2
Formal sub-test BIT scores [37] of the 12 neglect patients

Patient	Total score	Line crossing (36)	Star cancellation (54)	Letter cancellation (40)	Line bisection (9)	Copying (4)	Representational drawing (3)
J.C.F.	107	35	37	27	5	2	1
E.R.	116	34	40	27	8	4	3
R.P.	123	36	50	30	3	1	3
L.C.	115	35	41	30	5	1	3
H.J.	108	33	37	32	0	3	3
K.G.	126	35	53	31	0	4	3
C.P.	98	31	24	33	4	3	3
D.S.	86	36	24	19	3	3	1
A.F.	68	20	12	21	9	3	3
K.A.	101	34	33	20	8	3	3
J.R.	112	34	47	21	4	3	3
D.D.	35	18	5	8	3	0	1

Each line was separated from the following line by 17 mm. A mask for the stimulus sheet was constructed to form a window through which only one of the lines could be seen at a time, preventing comparisons of the present response with previous ones. The overhead projector used was a portable A4 square overhead projector (RS; ELMO; OHP 285S).

Participants were seated at a table, approximately 30 cm from the overhead projector, with the experimenter ensuring that the participants' body position did not change throughout the testing. Head- and eye-movements were not restricted. The transparency on the overhead projector was presented to the participants directly opposite the subject's body midline. It was placed in the centre of the projecting surface in the horizontal plane, its right/left borders aligned with the right/left border of the projecting surface. The vertical position of the transparency was flexible, to allow for different arm and, thus, reaching lengths within subjects. The stimuli were projected *mirror-reversed* onto a 2 m × 2 m screen at a distance of 2.3 m. The image on the wall was approximately 1.2 m × 1.2 m.

Participants were asked to put a mark in the centre of the line appearing in the viewing window: In the *congruent* condition, participants had full view of the projector's surface while trying to bisect the lines. They were instructed to transact the lines by looking at the surface of the projector (which was switched on), and to ignore the projection on the wall. To ensure this, the experimenter sat opposite the participant, between the participant and the screen. In the *incongruent* condition, direct viewing of the overhead projector's surface and the participants' hand was prevented by a cloth (590 mm × 420 mm) attached to the arm of the overhead projector. Participants were asked to transect each line projected onto the screen. In this condition the experimenter stood centrally behind the subject.

The order of the congruent versus incongruent condition was counterbalanced between participants. Twenty lines (10 lines × 2 conditions) had to be bisected overall. Errors in line bisection in both conditions were measured in millimetres, as the distance of the participants' bisection from the objective midpoint, *from the participants' point of view*, and then averaged across the 10 lines. Errors to the right (as seen by the participants) were given a positive value, errors to the left a negative value.

2.3. Task 2 (Pulley Device Task; adapted from Bisiach et al. [4])

A 160 mm high, 250 mm wide and 190 mm deep 'Pulley Box' was assembled. In the front and top part of the box, a viewing window measuring 35 mm in height and 160 mm in length was cut centrally, 45 mm from the left and the right edge of the box. Centrally positioned in that viewing window, on white paper, was a black line measuring 160 mm in length and 1.5 mm in width presented in the vertical plane. The bottom of the Pulley Device contained two handles, each 30 mm long and 7 mm wide. Connected to each

handle was one metal rod, measuring 5 mm in length. This rod was visible in the window, positioned in front of the line and served as a pointer. Moving each handle in the horizontal plane allowed the pointer to move along the length of the line. A ruler was positioned at the back of the Pulley Device and the tip of the pointer could be seen above the ruler, thus, allowing measurement of the deviation from the true midpoint. Below the window, in the front of the Pulley Device, a curtain hid the two handles and also the hand that would move them.

Participants were seated at a table opposite the experimenter, who made sure that the participant's body position did not change throughout the testing. Head- and eye-movements were not restricted. The Pulley Device was positioned directly in front of the patient, at a distance of about 45 cm, aligned with the body midline. Participants were asked to position the pointer in the centre of the line in two conditions: in the *congruent* condition, the pointer moved into the direction in which the subject pulled the handle. In the *incongruent* condition, the pointer moved into the *opposite* direction to which the handle was pulled. In both conditions the hand and the handle were hidden from view.

There were 10 trials for each condition, five of which started with the pointer on the right-side and five on the left-side of the Pulley Device, thus, adding to a total of 20 trials. Order of right/left starting points was randomised for each condition. The order of conditions was counterbalanced between subjects.

The deviations from the objective midpoint of the bisected line were measured in millimetres with rightward errors being assigned a positive value and leftward errors a negative value. The results from each trial were averaged across the five trials starting from the right and the five trials starting from the left, separately for each condition.

2.4. Task 3 (line bisection and Landmark Task, adapted from Milner et al. [25])

2.4.1. Line Bisection Task

Ten black lines of 200 mm length and 1 mm width were placed horizontally and centrally on one sheet of white A4 paper. Each line was separated from the following line by 17 mm. A mask for the stimulus sheet was constructed to form a window through which only one of the lines could be seen at a time, preventing comparisons of the present response with previous ones. Each participant was seated at a table opposite the experimenter who ensured that the participant's body position remained constant throughout the session. Head- and eye-movements were not restricted. The A4 sheet with the 10 horizontally aligned lines was placed beneath the mask directly opposite the subject's body midline (central location). Viewing distance was about 45 cm from the line that was to be bisected.

Participants were asked to put a mark in the centre of each line as accurately as possible. The examiner then moved the mask with the viewing window to the

following line, proceeding from the top to the bottom of the A4 sheet.

Errors in line bisection were measured in millimetres, as the distance between the true midpoint and the participant's bisection, and averaged across the 10 lines. Errors to the right of the true midpoint were given a positive sign, while errors to the left of the true midpoint were given a negative sign.

2.4.2. Landmark Task

Sixteen black lines of 200 mm length and 1.5 mm width were used, each line placed horizontally and centrally on a separate A4 sheet of white paper. Each line had been pre-transacted at a right angle. Six of these lines were asymmetrically transacted: three to the right of the true midpoint in distances of 1, 3 and 5 mm, and three to the left of the true midpoint in distances of 1, 3 and 5 mm. The other 10 lines had been pre-bisected in the centre. Participants were seated at a table opposite the experimenter, who ensured that their body position remained constant throughout the testing; head- and eye-movements were not restricted. The test was presented directly opposite the body midline (central position). Viewing distance was about 45 cm.

Participants were asked to point to the end of the line (either the right or the left end of the line) that seemed closer to the transaction mark. Previously, they had been falsely informed that none of the transactions were in the exact centre of the line and were, thus, forced to make a left/right choice—no other responses were acceptable. The lines were ordered in a random fashion, which was identical for each participant.

Landmark and line bisection blocks were counterbalanced across patients.

The number of left and right responses for lines pre-bisected in the centre were added. Additionally, errors (pointing to the right when a line was actually pre-bisected to the left of the true midpoint and vice versa) were recorded as well.

Tasks 2 and 3 were counterbalanced between participants as completely as possible, the incongruent part of the Overhead Task (Task 1), however, was perceived as difficult and time-consuming so Task 1 was always given last to ensure that, by this time, the subjects were more familiar with the experimenter and the general test demands. All three tasks were given within 2 weeks of initial experimental testing.

Due to the hemipareses the patients had, all right hemisphere-lesioned patients performed the three tasks with the right-hand and all left hemisphere-lesioned patients with their left-hand. The healthy controls performed all tasks with both their right- and left-hand, with hand and tasks counterbalanced as completely as possible.

3. Results

3.1. Classification

The mean performance and standard deviation of each patient for each of the three tasks are listed in Table 3 and can be compared to the average performance of the control groups. In Figs. 1 and 2, we plotted the performance of each patient in the congruent conditions against their performance in the incongruent conditions. Similarly, in Fig. 3 each patients' line bisection performance was plotted against their leftward-pointing behaviour (in %).

Table 3

Mean bisection error and S.D. (in mm) of individual neglect patients for the three tasks: congruent (CO) and incongruent (INC) conditions (Tasks 1 and 2); line bisection (LB, Task 3)^a

	Task 1: CO	Task 2: INC	Classification	Task 2: CO	Task 2: INC	Classification	Task 3: LB	Task 3: LM left/right	Classification
J.C.F.	28.3 (2.8)	−51.3 (8.6)	Premotor	2.6 (3.2)	0.9 (7.3)	Perceptual	11.4 (4.6)	100/0	Perceptual
E.R.	17.9 (3.2)	12.0 (6.2)	Perceptual	6.0 (2.8)	2.6 (1.2)	Perceptual	32.6 (6.0)	90/10	Perceptual
R.P.	24.7 (2.4)	−4.6 (25.9)	Premotor	−9.5 (4.9)	−1.0 (4.4)	Perceptual?	19.9 (6.5)	90/10	Perceptual
L.C.	26.9 (14.2)	−28.9 (18.3)	Premotor	11.2 (3.9)	−0.9 (2.8)	Premotor	21.9 (4.8)	100/0	Perceptual
H.J.	13.0 (3.2)	4.5 (5.0)	Perceptual	5.8 (3.2)	−2.6 (5.8)	Premotor	22.7 (6.1)	80/20	Perceptual
K.G.	13.0 (9.1)	31.2 (5.1)	Perceptual	3.6(4.9)	−8.2 (6.1)	Premotor	−9.9 (7.1)	50/50	?
C.P.	42.1 (7.5)	−7.0 (5.7)	Premotor	6.3 (3.4)	−0.9 (8.1)	Premotor	13.0 (5.7)	60/40	Perceptual
D.S.	15.3 (7.8)	−2.6 (2.0)	Premotor	0.4 (5.0)	−6.2 (3.1)	Premotor?	14.9 (6.5)	90/10	Perceptual
A.F.	11.1 (9.4)	1.4 (10.1)	Perceptual	0.3 (2.4)	−1.6 (3.8)	Premotor?	−5.3 (5.6)	0/100	Perceptual?
K.A.	7.7 (3.9)	−2.1 (14.5)	Premotor	0.0 (3.1)	3.1 (5.6)	Perceptual?	3.2 (2.8)	90/10	Perceptual
J.R.	15.5 (8.6)	−7.0 (8.2)	Premotor	3.8 (3.0)	−6.1 (4.3)	Premotor	6.4 (1.1)	100/0	Perceptual
D.D.	15.4 (6.7)	−22.1 (9.2)	Premotor	−14.0 (11.2)	−9.7 (18.5)	Perceptual?	−20.0 (9.0)	90/10	Premotor?
RH	2.1 (8.1)	3.8 (22.6)		−0.4 (2.7)	−2.1 (2.9)		0.8 (7.9)	58/42	
LH	−7.2 (7.4)	−1.4 (7.0)		−0.2 (0.8)	−4.4 (2.9)		−4.1 (5.2)	30/70	
HC	−0.1 (6.6)	−3.6 (5.7)		−0.3 (2.1)	−4.2 (2.9)		−1.4 (3.5)	65/35	

^a A positive sign indicates a rightward error and a negative sign a leftward error, as perceived from the patient's point of view. For comparison, mean bisection errors and standard deviations (in mm) for right hemisphere (RH) and left hemisphere (LH) lesioned control groups and the healthy control group (HC) are also supplied. For the Landmark Task (LM) percentages are given for each neglect patient and mean percentages for the control groups. See text for classification, ? = patient could not be categorised clearly (reasons in text).

Fig. 1. Scatterplot of the performance of the neglect patients in Task 1. Mean bisection and S.E. of each patient in the congruent condition are plotted against the incongruent condition. A positive sign indicates a rightward error and a negative sign a leftward error, as perceived from the patient's point of view. Patients falling in the upper right and lower left quadrant can roughly be categorised as 'perceptual' and those falling in the remainders as 'premotor' (see text).

Categorical classification of the patients is given in Table 3. In the figures, for all three tasks, patients falling in the upper right quadrant are classified as suffering from a mainly perceptual impairment: in the two congruent conditions (Tasks 1 and 2) and the line bisection test of Task 3 these patients made a rightward error that remained a rightward error from their perspective in the incongruent conditions and resulted in leftward-pointing in the Landmark Task. In principle,

Fig. 2. Scatterplot of the performance of the neglect patients in Task 2. Labelling and categorisation as in Fig. 1.

Fig. 3. Scatterplot of the performance of the neglect patients in Task 3. Mean bisection and S.E. of each patient in the Line Bisection Task are plotted against the percentage of leftward-pointing in the Landmark Task. Categorisation as in Fig. 1.

patients falling in the lower left quadrant would also be judged this way, albeit this requiring a leftward bisection error in the two congruent conditions (Tasks 1 and 2) that remained a leftward error from the subjects' perspective in the incongruent conditions. Also patients producing a leftward error in the line bisection test in Task 3 but rightward-pointing in the landmark Task would be classified in this way as they would be deemed to overestimate the left part of the line.

In contrast all patients falling in the lower right quadrant are classified as suffering from a mainly premotor impairment: in the two congruent conditions (Tasks 1 and 2) and the line bisection test of Task 3 these patients made a rightward error that changed into a leftward error from their perspective in the incongruent conditions and resulted in rightward-pointing in the Landmark Task. In principle, patients falling in the upper left quadrant would also be judged this way, albeit this requiring a leftward bisection error in the two congruent conditions (Tasks 1 and 2) that changed into a rightward error from their perspective in the incongruent conditions. Also patients producing a leftward error in the line bisection test in Task 3 and leftward-pointing in the Landmark Task would be classified in this way as they would be deemed to have a left premotor bias.

3.1.1. Task 1

All 12 neglect patients tested showed substantial rightward deviations in the congruent condition of the line bisection condition (Table 3). Out of these patients, eight patients reversed the direction of their bisection errors in the incongruent condition, bisecting the lines towards the left, as they perceived it, which means that their hand stayed in the right

hemispace. These patients were, therefore, classified as suffering from mainly premotor neglect (Fig. 1 and Table 3). The remaining four patients showed rightward bisection errors in both conditions and were, thus, classified as suffering from mainly perceptual neglect (Fig. 1 and Table 3).

3.1.2. Task 2

Out of the 12 neglect patients only 9 patients revealed a rightward bisecting error in the congruent condition and of those a further two showed only very small rightward bisection errors (Fig. 2 and Table 3). Of the remaining seven patients, five patients showed a rightward bisection error that reversed into a leftward bisection error in the incongruent condition, thus, revealing premotor neglect (Fig. 2). Only two patients displayed rightward errors in both the congruent and incongruent conditions and were thus classified as suffering from perceptual neglect (Fig. 2).

3.1.3. Task 3

Out of the 12 patients tested (Fig. 3 and Table 3), 9 patients showed substantial rightward errors in the Line Bisection Task. All of these nine patients pointed more frequently to the left in the Landmark Task, and were, thus, classified into the *perceptual neglect group* (Fig. 3). All of these patients also showed errors for lines asymmetrically bisected towards the right, in all cases falsely indicating that the left half of the line was shorter with lines that were bisected up to 5 mm towards the right. They never made errors for lines asymmetrically bisected to the left.

The remaining three neglect patients could not be classified easily (Fig. 3) as they bisected towards the *left* in the Line Bisection Task. One of these had also produced leftward errors in the Pulley Device (Task 2) and the remaining two showed only very small rightward errors in this task. It is possible that the line bisection impairment in these patients was not as grave as in the others. However, they were all clearly impaired on the congruent line bisection overhead version (Task 1).

3.2. Across task categorisation

When patients were compared across all three tasks it became apparent that only one patient (E.R.) was categorised in the same way. A total of 6 out of the 12 patients, were identified similarly in two out of the three tasks. Comparison of Task 1 and Task 2 identified four patients similarly whereas the comparison of Task 1 and Task 3 and also Task 2 and Task 3 classified only two patients in a similar manner.

4. Discussion

The main aim of the present study was to investigate whether the Overhead (Task 1, adapted from Nico [32]), Pulley Device (Task 2, adapted from Bisiach et al. [4]) and

Landmark Tasks (Task 3, adapted from Milner et al. [25]) categorised the same set of patients in the same way.

As in the previously reported studies, it was found that most patients could be classified into either the premotor or perceptual category in *each task*, however, no consistent categorisation emerged *across the three techniques*. It was clear that the Landmark Task (Task 3) classified the vast majority of patients into the perceptual neglect category, while the Overhead and Pulley Device Techniques (Tasks 1 and 2) identified more patients as suffering from a premotor deficit (albeit not the same set of patients).

These differences may relate to the different visuo-motor demands of each task. Both incongruent conditions of the Overhead and Pulley Device Task are motorically more complex than the Landmark Test which only requires a simple pointing response. For the Overhead Task in particular, a subjective rightward bisection requires a leftward movement co-ordinated not only in the horizontal but also the vertical and depth plane. This challenge may have induced the neglect patients to remain in a similar spatial position for a large proportion of the incongruent trials, thus, leading to the relatively large number of 'premotor' classifications for this task. Bisiach et al. [5] already noted that these techniques differ in their degree of naturalness or ecological validity and that a technique that is more visuo-spatially and motorically demanding is more sensitive to premotor factors. This explanation is consistent with the finding that only one patient was classified as having premotor neglect when assessed with the Landmark Task. It seems possible that a patient with a perhaps moderate premotor deficit might still be able to carry out the relatively simple movement of pointing towards the left, while a leftward movement in the complex environment provided by the Overhead and Pulley Device Techniques might be impossible. This hypothesis is supported by studies like Milner et al. [26], Milner and Harvey [28] and Harvey et al. [14] where the great majority of neglect patients tested with the Landmark Task was actually deemed to suffer from a perceptual distortion rather than a premotor bias. Bisiach et al. [6], on the other hand, used the Landmark Task on a large group of 121 neglect patients, and identified only 14 patients with pure perceptual neglect, but 36 patients with pure premotor neglect. However, contrary to the landmark studies carried out by Milner and co-workers, Bisiach et al.'s [6]. Landmark Task assessed the judgement of lines pre-bisected from 30 to 150 mm to the left and the right, with the actual line shorter than the line used by Milner and co-workers. It is possible that the proportionally higher number of premotor patients identified with Bisiach et al.'s version of the Landmark Task was due to the easier discriminability of the stimuli: in Milner and co-workers' version the majority of lines were actually pre-bisected in the centre, and the asymmetrically pre-bisected lines were bisected only up to 5 mm to the left and to the right of the true midpoint.

Mattingley and co-workers [20,22] have argued that the incongruent conditions in the Mirror and Pulley Technique, give rise to unnatural correspondences as the patients are

required to switch attention between spatially incompatible inputs from the visual and proprioceptive modalities and have to generate an appropriate response based on these incongruent inputs. Therefore, any emerging dissociation between the congruent and incongruent condition may simply reflect the susceptibility of patients to novel and highly incompatible situations rather than a true dichotomy. This could explain the high proportion of patients categorised as premotor (8/12 patients) for the Overhead Task; the task which clearly gave rise to the most incongruent inputs of the three tested here. Observing the neglect patients and controls on this task, it was clear that performance in the incongruent condition was slow and more troublesome overall: incongruent inputs clearly led to an increase in task difficulty.

Another reason for the perceived increase in task difficulty in this condition may have been the fact that stimuli were presented in far space and neglect symptoms can dissociate according to near/far space. In particular, lines being projected onto the wall are perceived as larger than those presented on the overhead surface and this increase in perceived length could also have led to greater task difficulty. Whatever the exact underlying reasons, this task was clearly the most difficult to execute and this seems to have led to a large proportion of patients being classified as premotor.

It was also found that all neglect patients made larger rightward bisection errors in the *congruent bisection condition of the overhead*, in particular when compared to the *congruent condition of the Pulley Device*. As the Overhead Task was always given last due to its perceived difficulty, it is unlikely that practice effects came into play. However, there seems to have been a task effect. Again observation of the patients showed that they perceived the elevated position of their hand on the overhead as difficult to deal with, an effect which could have resulted in a larger rightward bias. The relatively smaller and in part leftwards errors produced in the Pulley Device Task might have been due to the reduced line length and the set-up of this task, which was presented in the vertical plane rather than face-down in front of the subject. Dellatollas et al. [11] reported a rightward bias in healthy participants in a Line Bisection Task presented on a computer screen, whereas the same participants showed a weak leftward bias in line bisection on paper. It is, therefore, possible that different bisection biases can be found in both neglect and non-neglect subjects depending on the plane the task is carried out in. However, as the *pattern* of bisection performance in terms of the direction of the errors was comparable across the congruent conditions of Tasks 1 and 2 and also comparable to those of the line bisection data in Task 3, it is more likely that Task 2 picked up the bisection errors in the same way, but to a lesser degree.

Despite the fact that these three techniques essentially only required line bisection, their task demands still proved too diverse to allow a consistent categorisation across the patients. The Landmark Test used here is very likely to underestimate premotor factors contributing to hemispatial neglect whereas the Overhead Technique may do the

opposite. Applying these insights to the individual performance level, it seems that a particular neglect patient may be more likely to display any perceptual aspect of his/her syndrome in the Landmark Task as this test requires a relatively natural movement but display any premotor aspects of the syndrome in tasks such as the Overhead and Pulley Device for which visuo-manual and visual-proprioceptive demands are much higher. An alternative explanation to the dichotomy may, therefore, be to think of the premotor and perceptual symptoms shown by the majority of neglect patients as a continuum into which the different tasks tap into to varying degrees due to their varying task demands.

Given the inconsistencies of classifications across the three tasks administered here, it would appear to be premature to attribute perceptual and premotor neglect to specific lesion locations. Future work will need to make a more detailed and careful task analysis to qualify the nature and extent of the motor demands of each task. Only when these differences are explicit can a link with the neural substrates be sustained.

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