



# Bisecting or Not Bisecting: This Is the Neglect Question. Line Bisection Performance in the Diagnosis of Neglect in Right Brain-Damaged Patients

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## Abstract

In the present study we analysed the bisecting behaviour of 287 chronic right brain-damaged patients by taking into account the presence and severity of extrapersonal and/or personal neglect diagnosed with the hemineglect battery. We also analysed right brain-damaged patients who had (or did not have) neglect according to their line bisection performance. Our results showed that performance of the line bisection task correlates with performance of cancellation tasks, reading and perceptual tasks, but not with the presence of personal neglect. Personal neglect seems to be unrelated to line bisection behaviour. Indeed, patients affected by extrapersonal and personal neglect do not show more severe neglect in line bisection than patients with only extrapersonal neglect. Furthermore, we observed that 20.56% of the patients were considered affected or not by neglect on the line bisection task compared with the other spatial tasks of the hemineglect battery. We conclude that using a battery with multiple tests is the only way to guarantee a reliable diagnosis and effectively plan for rehabilitative training.

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## Introduction

Hemineglect is a common and disabling condition that often occurs following damage to one cerebral hemisphere. It is characterised by patients' unawareness of contralesional stimuli. In right brain-damaged patients it occurs subsequent to brain lesions with a prevalence of about 52.08% [1]. Hemineglect is most prominent and long-lasting after damage to the right hemisphere, particularly when it involves the posterior parietal cortex [2]. A recent meta-analysis [3] reported a wide range of cortical and sub-cortical lesions (subdivided into nine significant clusters) that produce hemineglect. Specifically, lesions involve the white matter corresponding to the posterior part of the superior longitudinal fasciculus and the following lesional clusters: the posterior middle temporal gyrus and angular gyrus, the inferior parietal lobule, the caudate nucleus, the horizontal segment of the intraparietal sulcus and postcentral sulcus, the pre-cuneus, the superior temporal gyrus and superior temporal sulcus, the posterior insula and the middle occipital gyrus [3]. Also supporting this large lesional variability, a growing body of evidence suggests that hemineglect is not a unitary syndrome but encompasses different disorders that affect the perceptual, personal or representational domains [2] [4]. When hemineglect involves perceptual domains, patients fail to cross out targets scattered on a sheet of paper in front of them, to read the left side of sentences or even of single words, to eat on the left side of the dish and in general to find an object on their contralesional side. Differently, when hemineglect affects the personal domain, patients fail to put

their glasses on the left ear, put on the left sleeve of their jacket or their left shoe [5] [6]. Due to evidence that hemineglect is not heterogeneous in its manifestations in clinical practice, the condition is typically assessed with a battery of tests rather than a single one. Indeed, patients who perform normally on some tests may show clinically significant neglect on others [7]. According to Saj et al. [8] the major differences in findings may depend on the clinical measures used. For example, differences in assessment methods might determine the frequency of occurrence of neglect (which ranges from 13% to 82%) [9]. Hemineglect can be assessed with different tests: cancellation tests [10] [11] [12], line bisection [10], drawing and copying tests [10], imagery tests [13] [14], reading of texts [15], description of objects and scenes and functional tasks [10]. Verdon et al. [16] carried out a factorial analysis by extracting three different components (perceptual, visuo-motor and object-based neglect aspects) from several neglect-detecting tasks. The perceptual aspects were derived from patients' deviation on line bisection and their contralesional word omissions in two reading tasks. Specifically, the visuo-motor aspect was derived from contralesional misses in different cancellation tasks and the object-based neglect aspect was derived from transformations of the left side of words during reading and the left side of targets during the Ota search task [17]. The skills assessed by drawing were related to both perceptual and visuo-motor aspects [16].

Saj et al. [8] found that the components which account for hemineglect patients' performance in the acute and chronic phases were very similar in spite of significant changes in the severity of

neglect revealed in several tests. They reported that acute hemineglect patients' performance across tests was characterised by five main factors regrouped as follows: (a) contralesional omissions in cancellation tasks, in clock drawing and in writing; (b) left–right difference in cancellation tasks; (c) omissions in scene copying and text reading; (d) short and long line bisection; and (e) temporal slowing on cancellation tasks. Chronic hemineglect patients' performance was characterised by four factors regrouped as follows: (a) contralesional omissions in cancellation, writing and in all drawing tasks; (b) left–right difference in cancellation tasks; (c) deviation in line bisection and reading errors; and (d) deviation in line bisection and temporal slowing.

The aim of the present study was to analyse the bisecting behaviour of chronic right brain-damaged patients by taking into account the presence and severity of perceptual neglect assessed by several paper and pencil tests and the presence of personal neglect. We also analysed right brain-damaged patients who had neglect or not according to their line bisection performance.

## Methods

### Participants

We recruited 282 right brain-damaged patients with sequelae of single strokes who were admitted consecutively to the I.R.C.C.S. Fondazione Santa Lucia in Rome and who showed no comprehension deficits or mental decay on the neuropsychological assessment at admission. Patients were subdivided into two groups according to the presence/absence of visuo-spatial hemineglect: 157 patients (54 females and 103 males; mean age 67.39 years, S.D. = 12.71 years; mean years of education, 9.24 years, S.D. = 4.67 years; and mean distance from onset, 639.80 days, S.D. = 1602.68 days) who showed no signs of hemineglect and the remaining 125 patients (59 females and 66 males; mean age 64.45 years, S.D. = 14.24 years; mean years of education, 9.38 years, S.D. = 4.79 years; and mean distance from onset 209.30 days, S.D. = 392.39 days) who suffered from hemineglect.

A control group of 91 healthy participants matched for age, gender and education with the right brain-damaged patient group (46 females and 45 males, mean age 62.95 years, S.D. = 10.66 years; mean years of education = 9.55 years, S.D. = 4.26 years) was also recruited to obtain the normal degree of asymmetries in line bisection (BIT). Two, one-way ANOVAs showed that patients (Neg and NoNeg) did not differ from healthy participants for age ( $F_{(2,370)} = 2.55$ ;  $p = 0.08$ ; effect size ( $r = .01$ ) or education ( $F_{(2,370)} = 0.12$ ;  $p = 0.89$ ; effect size ( $r = .001$ )).

The examiner explained the purpose of the research to the participants and responded to their questions and concerns. Exclusion criteria included a history of multiple cerebrovascular accidents, general cognitive decay and previous neurological or psychiatric disorders. The study protocol, which was in accordance with the ethical principles of the Declaration of Helsinki, was approved by the local ethics committee (I.R.C.C.S. Fondazione Santa Lucia of Rome, Italy). All patients were *compos mentis* and signed written consent forms before taking part in the experimental testing.

### Neuropsychological Assessment

All patients were submitted to an extensive neuropsychological assessment to investigate their orientation in time and space, personal orientation [18], language functions [19], visuo-spatial and verbal short-term and working memory [18], long-term verbal memory [18], abstract and/or verbal reasoning [20] [18], attention and agnosia [18]. Patients' performance on the neuropsychological tests was used to rule out general mental

decay and visuo-spatial disorders not restricted to the contralesional hemifield.

A standard battery for evaluating the neglect syndrome [15] was used to determine whether perceptual neglect was present and, if so, its severity (see Table 1). The battery includes four conventional tests:

*Letter Cancellation Test* [modified by 9 included in 15]: Subjects' task is to cross out 104 uppercase "H's" interspersed among 386 different letters arranged in 6 horizontal lines on a sheet of A3 paper (total score range 0–104; 0–53 on the left, 0–51 on the right). The sheet is presented centrally in front of the patient. The cut-off is a difference  $\geq 4$  between omissions on the left and the right side. The maximum number of omission errors in healthy subjects is four; the maximum difference between errors on the left and the right is two [21].

*Line Cancellation Test* [modified by 8 included in 15]: 21 lines with different orientations (3 cm long) are randomly dispersed on a sheet of A3 paper presented centrally in front of subjects (total score range 0–21; 0–11 on the left, 0–10 on the right). Subjects have to cross out all the lines they can find without a time limit. The cut-off is  $\geq 2$  omissions on the left side. Healthy subjects make no errors on this test.

*Wundt-Jastrow Area Illusion Test* [19 included in 15]: Subjects are presented with a picture of two identical black fans placed one above the other so that one of them appears horizontal; they have to point to the stimulus that seems longest (illusionary effect). In 20 trials the illusory effect is present in left-oriented stimuli and in 20 trials in right-oriented stimuli. In neglect patients, the illusory effect is reduced on the contralesional side [22]. The score is the number of trials in which the normal illusory effect is present on each side (score range 0–20). The cut-off is a difference of 2 between unexpected responses (i.e., responses in the direction opposite the illusory effect in controls) for left-oriented minus right-oriented stimuli.

*Sentence reading* [15]: The patient has to read aloud six sentences ranging from 5 to 11 words (21–42 letters). The score is the number of correctly read sentences (score range 0–6). The cut-off is one or more sentences read incompletely on the left side. Healthy subjects and right brain-damaged patients without hemineglect make no errors. Patients with neglect [15] make omission errors, substitution errors or both in the left half of the sentence as reported in the original paper by Pizzamiglio and co-workers [15].

In accordance with normative rules, the patients were classified as affected by perceptual neglect (Neg) if they scored below the cut-off on at least two of the four tests.

We also assessed the presence of personal neglect by administering the *Use of Common Objects* test [23], which requires using three objects (eyeglasses, a razor, or face powder and a comb) in the body space. For each object, the clinical neuropsychologist assigned a score from 0 to 3 on the basis of the asymmetry of the patient's performance in the left and right space (0 = no asymmetry, 3 = maximal asymmetry). The final score was the sum of the three distinct evaluations obtained for the three objects; the cut-off was 2 (0–1 = absence of personal neglect, 2–9 = minor to severe personal neglect). A diagnosis of personal neglect was made if the total score on the Use of Common Objects test was greater than or equal to 2 [24].

### Experimental Procedure

**Line bisection task.** Patients were required to bisect three black horizontal lines that were 200 mm long and 2.5 mm thick. The lines were presented on a table: each was centred on a horizontally oriented sheet of A4 white paper. The centre of all the

**Table 1.** Clinical data of patients classified according to the standard battery for evaluating Neglect syndrome [15].

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           |           |         | Wundt-Jastrow |           |          |  | Personal Neglect |  | Line Bisection |  | Lesion site |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|-----------|---------|---------------|-----------|----------|--|------------------|--|----------------|--|-------------|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6) | Reading | (9)           | Mean (mm) | (right)  |  |                  |  |                |  |             |
| Pt1               | Yes              | Severe            | 3         | 3          | 6         | 8                   | 6         | 3         | 5       | 5             | -17.5     | F        |  |                  |  |                |  |             |
| Pt2               | Yes              | Severe            | 2         | 10         | 0         | 12                  | 14        | 4         | 3       | 3             | 1.33      | F-T      |  |                  |  |                |  |             |
| Pt3               | Yes              | Moderate          | 11        | 10         | 22        | 50                  | 5         | 5         | 5       | 5             | -8        | F-T-P i  |  |                  |  |                |  |             |
| Pt4               | Yes              | Moderate          | 8         | 10         | 1         | 37                  | 1         | 3         | 6       | 6             | -8.33     | F-T-P    |  |                  |  |                |  |             |
| Pt5               | Yes              | Moderate          | 11        | 10         | 0         | 19                  | 20        | 1         | 5       | 5             | -12       | F-T-P    |  |                  |  |                |  |             |
| Pt6               | No               | Moderate          | 11        | 10         | 14        | 38                  | 6         | 5         | 0       | 0             | -4        | F-T      |  |                  |  |                |  |             |
| Pt7               | No               | Moderate          | 9         | 10         | 0         | 20                  | 10        | 6         | 1       | 1             | 0.2       | F        |  |                  |  |                |  |             |
| Pt8               | Yes              | Moderate          | 7         | 10         | 0         | 34                  | 9         | 6         | 4       | 4             | 2.33      | F-T-P    |  |                  |  |                |  |             |
| Pt9               | Yes              | Moderate          | 11        | 10         | 0         | 36                  | 11        | 4         | 3       | 3             | 5.67      | ---      |  |                  |  |                |  |             |
| Pt10              | Yes              | Moderate          | 2         | 10         | 0         | 5                   | 7         | 6         | 6       | 6             | 0.33      | T        |  |                  |  |                |  |             |
| Pt11              | No               | Moderate          | 11        | 10         | 32        | 51                  | 6         | 2         | 0       | 0             | 3         | ---      |  |                  |  |                |  |             |
| Pt12              | No               | Moderate          | 11        | 10         | 0         | 10                  | 20        | 1         | 0       | 0             | 5.67      | F-T-P    |  |                  |  |                |  |             |
| Pt13              | No               | Moderate          | 9         | 9          | 40        | 47                  | 11        | 0         | 0       | 0             | 0         | Th       |  |                  |  |                |  |             |
| Pt14              | No               | Moderate          | 11        | 9          | 33        | 51                  | 12        | 4         | 0       | 0             | 0         | F-T-P    |  |                  |  |                |  |             |
| Pt15              | Yes              | Mild              | 1         | 10         | 53        | 49                  | 6         | 6         | 5       | 5             | -6.67     | Ln       |  |                  |  |                |  |             |
| Pt16              | No               | Mild              | 11        | 10         | 5         | 50                  | 10        | 6         | 1       | 1             | -3        | F-T      |  |                  |  |                |  |             |
| Pt17              | Yes              | Mild              | 11        | 10         | 37        | 51                  | 0         | 5         | 3       | 3             | -1        | F-T      |  |                  |  |                |  |             |
| Pt18              | Yes              | Mild              | 11        | 10         | 4         | 35                  | 9         | 6         | 6       | 6             | 6         | F        |  |                  |  |                |  |             |
| Pt19              | Yes              | Mild              | 11        | 10         | 26        | 50                  | 0         | 1         | 2       | 2             | 6.33      | F        |  |                  |  |                |  |             |
| Pt20              | Yes              | Mild              | 10        | 10         | 39        | 41                  | 9         | 6         | 4       | 4             | -4.67     | T-P      |  |                  |  |                |  |             |
| Pt21              | Yes              | Mild              | 7         | 11         | 36        | 41                  | 1         | 6         | 3       | 3             | 1.33      | ---      |  |                  |  |                |  |             |
| Pt22              | Yes              | Mild              | 11        | 10         | 44        | 51                  | 3         | 6         | 2       | 2             | 5.33      | ic       |  |                  |  |                |  |             |
| Pt23              | Yes              | Mild              | 10        | 10         | 0         | 43                  | 5         | 6         | 4       | 4             | 1         | F-T-P    |  |                  |  |                |  |             |
| Pt24              | No               | Mild              | 11        | 10         | 44        | 47                  | 0         | 5         | 0       | 0             | 3.33      | ---      |  |                  |  |                |  |             |
| Pt25              | Yes              | Mild              | 11        | 10         | 41        | 44                  | 3         | 6         | 2       | 2             | 5         | ic th    |  |                  |  |                |  |             |
| Pt26              | Yes              | Mild              | 10        | 10         | 9         | 45                  | 0         | 0         | 2       | 2             | -3.67     | T-P-O    |  |                  |  |                |  |             |
| Pt27              | Yes              | Mild              | 11        | 10         | 50        | 51                  | 2         | 2         | 4       | 4             | 5.67      | F-T      |  |                  |  |                |  |             |
| Pt28              | No               | Mild              | 11        | 10         | 20        | 50                  | 2         | 6         | 0       | 0             | 4.67      | F-T-P ic |  |                  |  |                |  |             |
| Pt60              | Yes              | Severe            | 0         | 6          | 0         | 11                  | 12        | 0         | 4       | 4             | 24.3      | F-T-P    |  |                  |  |                |  |             |
| Pt61              | Yes              | Severe            | 0         | 10         | 0         | 8                   | 16        | 0         | 7       | 7             | 16.7      | F-T-P    |  |                  |  |                |  |             |
| Pt62              | Yes              | Severe            | 0         | 6          | 0         | 10                  | 14        | 0         | 7       | 7             | 13.3      | T-P      |  |                  |  |                |  |             |
| Pt63              | Yes              | Severe            | 5         | 10         | 7         | 45                  | 8         | 3         | 6       | 6             | 10.3      | ---      |  |                  |  |                |  |             |
| Pt64              | Yes              | Severe            | 7         | 10         | 0         | 42                  | 20        | 5         | 3       | 3             | 16.7      | ---      |  |                  |  |                |  |             |

Table 1. Cont.

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           |           |     | Wundt-Jastrow |         | Reading          |  | Personal Neglect |  | Line Bisection |  | Lesion site |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|-----------|-----|---------------|---------|------------------|--|------------------|--|----------------|--|-------------|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6) | (9) | Mean (mm)     | (right) |                  |  |                  |  |                |  |             |
| Pt65              | Neg              | Yes               | Severe    | 0          | 9         | 0                   | 19        | 7         | 1   | 3             | 13.3    | F-T-P            |  |                  |  |                |  |             |
| Pt66              | Neg              | No                | Severe    | 0          | 10        | 0                   | 3         | 20        | 0   | 1             | 47      | T-P              |  |                  |  |                |  |             |
| Pt67              | Neg              | Yes               | Severe    | 8          | 10        | 48                  | 51        | 12        | 1   | 6             | 16.7    | T-P              |  |                  |  |                |  |             |
| Pt68              | Neg              | Yes               | Severe    | 4          | 10        | 0                   | 22        | 19        | 5   | 6             | 13.7    | F-T              |  |                  |  |                |  |             |
| Pt69              | Neg              | Yes               | Severe    | 9          | 10        | 44                  | 49        | 17        | 1   | 4             | 24.3    | F-T-P            |  |                  |  |                |  |             |
| Pt70              | Neg              | Yes               | Severe    | 5          | 10        | 0                   | 44        | 11        | 4   | 5             | 13.3    | bg               |  |                  |  |                |  |             |
| Pt71              | Neg              | Yes               | Severe    | 9          | 10        | 1                   | 9         | 4         | 4   | 4             | 20.7    | F-T-P            |  |                  |  |                |  |             |
| Pt72              | Neg              | Yes               | Severe    | 9          | 10        | 0                   | 24        | 4         | 2   | 5             | 22      | F-T-P            |  |                  |  |                |  |             |
| Pt73              | Neg              | Yes               | Severe    | 1          | 10        | 0                   | 47        | 13        | 1   | 4             | 14      | F-T-P            |  |                  |  |                |  |             |
| Pt74              | Neg              | Yes               | Severe    | 9          | 10        | 0                   | 24        | 16        | 2   | 3             | 22.7    | ---              |  |                  |  |                |  |             |
| Pt75              | Neg              | Yes               | Severe    | 0          | 9         | 0                   | 8         | 14        | 0   | 6             | 28      | ---              |  |                  |  |                |  |             |
| Pt76              | Neg              | Yes               | Severe    | 0          | 7         | 0                   | 6         | 16        | 1   | 7             | 23      | F-P              |  |                  |  |                |  |             |
| Pt77              | Neg              | Yes               | Severe    | 3          | 10        | 0                   | 14        | 9         | 2   | 8             | 19.3    | F-T-P            |  |                  |  |                |  |             |
| Pt78              | Neg              | Yes               | Severe    | 0          | 9         | 0                   | 16        | 19        | 0   | 4             | 15.3    | P                |  |                  |  |                |  |             |
| Pt79              | Neg              | Yes               | Severe    | 2          | 10        | 0                   | 32        | 16        | 0   | 3             | 16.7    | T                |  |                  |  |                |  |             |
| Pt80              | Neg              | Yes               | Severe    | 3          | 10        | 0                   | 11        | 18        | 3   | 5             | 25      | ---              |  |                  |  |                |  |             |
| Pt81              | Neg              | Yes               | Severe    | 1          | 9         | 0                   | 16        | 12        | 0   | 4             | 28.3    | F-T-P            |  |                  |  |                |  |             |
| Pt82              | Neg              | Yes               | Severe    | 0          | 6         | 0                   | 4         | 20        | 0   | 5             | 43.3    | F-T-P            |  |                  |  |                |  |             |
| Pt83              | Neg              | Yes               | Severe    | 0          | 6         | 0                   | 9         | 17        | 1   | 6             | 22.7    | ---              |  |                  |  |                |  |             |
| Pt84              | Neg              | No                | Severe    | 6          | 7         | 0                   | 40        | 10        | 5   | 0             | 33.7    | F-T-O i ic th cr |  |                  |  |                |  |             |
| Pt85              | Neg              | Yes               | Severe    | 0          | 6         | 0                   | 2         | 15        | 0   | 6             | 28      | F-T-P ic In      |  |                  |  |                |  |             |
| Pt86              | Neg              | No                | Severe    | 0          | 10        | 0                   | 29        | 11        | 0   | 0             | 37.3    | ---              |  |                  |  |                |  |             |
| Pt87              | Neg              | Yes               | Severe    | 0          | 8         | 0                   | 5         | 20        | 1   | 4             | 31.3    | F-P              |  |                  |  |                |  |             |
| Pt88              | Neg              | Yes               | Severe    | 0          | 6         | 0                   | 2         | 13        | 0   | 7             | 39.7    | cr put gp        |  |                  |  |                |  |             |
| Pt89              | Neg              | Yes               | Severe    | 9          | 10        | 0                   | 11        | 20        | 1   | 3             | 27      | F-T-P            |  |                  |  |                |  |             |
| Pt90              | Neg              | Yes               | Severe    | 0          | 2         | 0                   | 6         | 20        | 0   | 9             | 65      | ---              |  |                  |  |                |  |             |
| Pt91              | Neg              | Yes               | Severe    | 7          | 10        | 11                  | 42        | 12        | 1   | 3             | 47.7    | F bg             |  |                  |  |                |  |             |
| Pt92              | Neg              | Yes               | Severe    | 0          | 5         | 0                   | 7         | 15        | 0   | 2             | 28      | ---              |  |                  |  |                |  |             |
| Pt93              | Neg              | No                | Severe    | 0          | 9         | 0                   | 9         | 13        | 1   | 1             | 49.7    | ---              |  |                  |  |                |  |             |
| Pt94              | Neg              | Yes               | Severe    | 2          | 10        | 3                   | 41        | 11        | 0   | 6             | 72.7    | T-P              |  |                  |  |                |  |             |
| Pt95              | Neg              | Yes               | Severe    | 0          | 8         | 0                   | 18        | 18        | 0   | 5             | 72.3    | ---              |  |                  |  |                |  |             |
| Pt96              | Neg              | Yes               | Severe    | 0          | 3         | 0                   | 12        | 20        | 0   | 6             | 59.3    | O ic th          |  |                  |  |                |  |             |
| Pt97              | Neg              | No                | Severe    | 0          | 7         | 0                   | 9         | 20        | 0   | 0             | 75      | P-O              |  |                  |  |                |  |             |

Table 1. Cont.

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           |            |           | Wundt-Jastrow |           | Reading    |           | Personal Neglect |     | Line Bisection |              | Lesion site |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|------------|-----------|---------------|-----------|------------|-----------|------------------|-----|----------------|--------------|-------------|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (20) | Left (20) | Right (20)    | Left (20) | Right (20) | Mean (mm) | (9)              | (9) | Mean (mm)      | (right)      |             |
| Pt98              | Neg              | Yes               | Severe    | 4          | 9         | 0                   | 13        | 6          | 0         | 0             | 3         | 68.7       | 0         | 3                | 0   | 68.7           | O            |             |
| Pt99              | Neg              | No                | Severe    | 0          | 6         | 0                   | 20        | 20         | 0         | 0             | 1         | 51.5       | 0         | 1                | 0   | 51.5           | ic           |             |
| Pt100             | Neg              | Yes               | Severe    | 1          | 8         | 0                   | 7         | 13         | 0         | 0             | 5         | 84         | 0         | 5                | 0   | 84             | F-P-O        |             |
| Pt101             | Neg              | Yes               | Severe    | 0          | 9         | 0                   | 18        | 14         | 0         | 0             | 6         | 45         | 0         | 6                | 0   | 45             | ---          |             |
| Pt102             | Neg              | Yes               | Moderate  | 0          | 7         | 44                  | 44        | 13         | 2         | 2             | 4         | 12.7       | 0         | 4                | 0   | 12.7           | ---          |             |
| Pt103             | Neg              | Yes               | Moderate  | 10         | 10        | 0                   | 44        | 6          | 5         | 5             | 5         | 9          | 0         | 5                | 0   | 9              | P            |             |
| Pt104             | Neg              | Yes               | Moderate  | 11         | 10        | 25                  | 51        | 5          | 3         | 3             | 4         | 7.3        | 0         | 4                | 0   | 7.3            | P cn ln ic   |             |
| Pt105             | Neg              | Yes               | Moderate  | 11         | 10        | 0                   | 41        | 3          | 2         | 2             | 3         | 10.7       | 0         | 3                | 0   | 10.7           | T-P          |             |
| Pt106             | Neg              | Yes               | Moderate  | 11         | 10        | 4                   | 35        | 7          | 1         | 1             | 2         | 10.3       | 0         | 2                | 0   | 10.3           | F th         |             |
| Pt107             | Neg              | No                | Moderate  | 11         | 10        | 17                  | 44        | 3          | 0         | 0             | 0         | 10.7       | 0         | 0                | 0   | 10.7           | F-P          |             |
| Pt108             | Neg              | No                | Moderate  | 10         | 10        | 23                  | 47        | 3          | 2         | 2             | 0         | 13.3       | 0         | 0                | 0   | 13.3           | T-P          |             |
| Pt109             | Neg              | No                | Moderate  | 11         | 10        | 17                  | 47        | 2          | 3         | 3             | 1         | 12         | 0         | 1                | 0   | 12             | F-T          |             |
| Pt110             | Neg              | No                | Moderate  | 11         | 10        | 6                   | 37        | 7          | 1         | 1             | 1         | 13         | 0         | 1                | 0   | 13             | T bg         |             |
| Pt111             | Neg              | Yes               | Moderate  | 10         | 10        | 33                  | 44        | 10         | 5         | 5             | 3         | 15.3       | 0         | 3                | 0   | 15.3           | ic           |             |
| Pt112             | Neg              | Yes               | Moderate  | 10         | 10        | 1                   | 16        | 12         | 3         | 3             | 2         | 29.3       | 0         | 2                | 0   | 29.3           | F-T-P        |             |
| Pt113             | Neg              | Yes               | Moderate  | 11         | 10        | 14                  | 35        | 3          | 4         | 4             | 2         | 18         | 0         | 2                | 0   | 18             | F-T-P i      |             |
| Pt114             | Neg              | Yes               | Moderate  | 10         | 10        | 11                  | 31        | 7          | 4         | 4             | 5         | 19.3       | 0         | 5                | 0   | 19.3           | F-P cr sc    |             |
| Pt115             | Neg              | Yes               | Moderate  | 10         | 10        | 0                   | 4         | 12         | 0         | 0             | 4         | 14.3       | 0         | 4                | 0   | 14.3           | F-P i ln     |             |
| Pt116             | Neg              | Yes               | Moderate  | 10         | 10        | 12                  | 51        | 5          | 4         | 4             | 4         | 18.3       | 0         | 4                | 0   | 18.3           | T-P          |             |
| Pt117             | Neg              | Yes               | Moderate  | 11         | 10        | 28                  | 41        | 7          | 4         | 4             | 3         | 15.7       | 0         | 3                | 0   | 15.7           | ic ln cn cr  |             |
| Pt118             | Neg              | Yes               | Moderate  | 10         | 10        | 14                  | 36        | 2          | 0         | 0             | 5         | 20.3       | 0         | 5                | 0   | 20.3           | T-P ln       |             |
| Pt119             | Neg              | Yes               | Moderate  | 9          | 10        | 0                   | 36        | 1          | 5         | 5             | 3         | 13         | 0         | 3                | 0   | 13             | T            |             |
| Pt120             | Neg              | Yes               | Moderate  | 10         | 10        | 38                  | 46        | 2          | 1         | 1             | 8         | 24.7       | 0         | 8                | 0   | 24.7           | ---          |             |
| Pt121             | Neg              | Yes               | Moderate  | 11         | 10        | 35                  | 51        | 20         | 4         | 4             | 2         | 19         | 0         | 2                | 0   | 19             | F-P sc       |             |
| Pt122             | Neg              | Yes               | Moderate  | 11         | 10        | 0                   | 21        | 18         | 0         | 0             | 5         | 30         | 0         | 5                | 0   | 30             | F-T-P        |             |
| Pt123             | Neg              | Yes               | Moderate  | 10         | 10        | 0                   | 34        | 9          | 4         | 4             | 3         | 20.3       | 0         | 3                | 0   | 20.3           | T-P          |             |
| Pt124             | Neg              | Yes               | Moderate  | 10         | 10        | 0                   | 48        | 15         | 0         | 0             | 5         | 42.3       | 0         | 5                | 0   | 42.3           | T-P          |             |
| Pt125             | Neg              | Yes               | Moderate  | 11         | 10        | 1                   | 40        | 14         | 1         | 1             | 3         | 44         | 0         | 3                | 0   | 44             | ln ic th ec  |             |
| Pt126             | Neg              | No                | Moderate  | 10         | 10        | 39                  | 49        | 3          | 3         | 3             | 1         | 24.7       | 0         | 1                | 0   | 24.7           | F-T-P        |             |
| Pt127             | Neg              | Yes               | Moderate  | 4          | 10        |                     |           | 20         | 0         | 0             | 5         | 51         | 0         | 5                | 0   | 51             | sc cr        |             |
| Pt128             | Neg              | No                | Moderate  | 0          | 8         |                     |           | 19         | 0         | 0             | 0         | 62.7       | 0         | 0                | 0   | 62.7           | F-T-P sc     |             |
| Pt129             | Neg              | Yes               | Moderate  | 10         | 10        | 0                   | 23        | 19         | 0         | 0             | 6         | 52.3       | 0         | 6                | 0   | 52.3           | T-P          |             |
| Pt130             | Neg              | Yes               | Moderate  | 0          | 10        | 0                   | 40        | 0          | 0         | 0             | 5         | 44.3       | 0         | 5                | 0   | 44.3           | F-T ic ln cr |             |

Table 1. Cont.

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           |           |                      | Wundt-Jastrow |               | Reading     |                      | Personal Neglect |               | Line Bisection |             | Lesion site |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|-----------|----------------------|---------------|---------------|-------------|----------------------|------------------|---------------|----------------|-------------|-------------|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6) | Personal Neglect (9) | Mean (mm)     | Right (right) | Left (left) | Personal Neglect (9) | Mean (mm)        | Right (right) | Left (left)    | Lesion site |             |
| Pt131             | Neg              | Moderate          | 0         | 6          |           |                     | 20        | 0         | 6                    | 81.7          | P-O           |             | 6                    |                  |               |                |             |             |
| Pt132             | Neg              | Moderate          | 11        | 10         | 9         | 49                  | 12        | 1         | 2                    | 75.7          | th sc         |             | 2                    |                  |               |                |             |             |
| Pt133             | Neg              | Moderate          | 0         | 5          | 0         | 11                  | 19        | 6         | 1                    | 79            | bg hth        |             | 1                    |                  |               |                |             |             |
| Pt134             | Neg              | Moderate          | 0         | 3          |           |                     | 20        | 0         | 5                    | 79.7          | F-T-P ic      |             | 5                    |                  |               |                |             |             |
| Pt135             | Neg              | Moderate          | 0         | 8          | 0         | 7                   |           | 0         | 4                    | 22            | P-O cn sc     |             | 4                    |                  |               |                |             |             |
| Pt136             | Neg              | Mild              | 11        | 10         | 45        | 49                  | 4         | 6         | 2                    | 7             | ic ln cr cn   |             | 2                    |                  |               |                |             |             |
| Pt137             | Neg              | Mild              | 10        | 10         | 21        | 22                  | 11        |           | 0                    | 11.7          | gp sc         |             | 0                    |                  |               |                |             |             |
| Pt138             | Neg              | Mild              | 11        | 10         | 37        | 38                  | 4         | 5         | 4                    | 10.3          | F-T-P         |             | 4                    |                  |               |                |             |             |
| Pt139             | Neg              | Mild              | 11        | 10         | 2         | 40                  | 5         | 6         | 0                    | 24            | F-P-O sc      |             | 0                    |                  |               |                |             |             |
| Pt140             | Neg              | Mild              | 10        | 10         | 12        | 26                  | 6         | 6         | 0                    | 13            | T             |             | 0                    |                  |               |                |             |             |
| Pt141             | Neg              | Mild              | 11        | 10         | 47        | 49                  | 9         | 6         | 1                    | 7             | F i           |             | 1                    |                  |               |                |             |             |
| Pt142             | Neg              | Mild              | 11        | 10         | 0         | 7                   | 1         | 0         | 0                    | 25            | F             |             | 0                    |                  |               |                |             |             |
| Pt143             | Neg              | Mild              | 11        | 10         | 30        | 49                  | 3         | 6         | 6                    | 7.7           | F-T i         |             | 6                    |                  |               |                |             |             |
| Pt144             | Neg              | Mild              | 11        | 10         | 9         | 46                  | 1         | 1         | 4                    | 9.3           | T             |             | 4                    |                  |               |                |             |             |
| Pt145             | Neg              | Mild              | 11        | 10         | 48        | 50                  | 2         | 6         | 4                    | 9.3           | O ic ln sc    |             | 4                    |                  |               |                |             |             |
| Pt146             | Neg              | Mild              | 11        | 10         | 21        | 27                  | 2         | 6         | 7                    | 16.7          | ---           |             | 7                    |                  |               |                |             |             |
| Pt147             | Neg              | Mild              | 10        | 10         | 50        | 51                  | 18        | 0         | 2                    | 28            | P-O           |             | 2                    |                  |               |                |             |             |
| Pt148             | Neg              | Mild              | 11        | 10         | 45        | 50                  | 15        | 6         | 2                    | 30.3          | F-T           |             | 2                    |                  |               |                |             |             |
| Pt149             | Neg              | Mild              | 11        | 10         | 0         | 12                  | 7         | 6         | 4                    | 18            | T-P i         |             | 4                    |                  |               |                |             |             |
| Pt150             | Neg              | Mild              | 10        | 10         | 36        | 34                  | 0         | 5         | 0                    | 10.7          | ---           |             | 0                    |                  |               |                |             |             |
| Pt151             | Neg              | Mild              | 10        | 10         | 13        | 51                  | 4         |           | 3                    | 9.7           | ---           |             | 3                    |                  |               |                |             |             |
| Pt152             | Neg              | Mild              | 11        | 10         | 12        | 36                  | 0         | 5         | 6                    | 8.7           | F-P           |             | 6                    |                  |               |                |             |             |
| Pt153             | Neg              | Mild              | 11        | 10         | 27        | 42                  | 0         | 3         | 2                    | 25.7          | F-T ic        |             | 2                    |                  |               |                |             |             |
| Pt154             | Neg              | Mild              | 10        | 10         | 0         | 36                  | 0         | 1         | 2                    | 21.7          | T             |             | 2                    |                  |               |                |             |             |
| Pt155             | Neg              | Mild              | 10        | 10         | 48        | 50                  | 7         | 6         | 1                    | 24.3          | F-T-P th      |             | 1                    |                  |               |                |             |             |
| Pt156             | Neg              | Mild              | 0         | 3          |           |                     |           | 0         | 0                    | 50.7          | F-T-P         |             | 0                    |                  |               |                |             |             |
| Pt29              | NoNeg            | Borderline        | 11        | 10         | 32        | 50                  | 0         | 6         | 3                    | 12.33         | F             |             | 3                    |                  |               |                |             |             |
| Pt30              | NoNeg            | Borderline        | 11        | 10         | 45        | 51                  | 1         | 6         | 1                    | 10.33         | F-T           |             | 1                    |                  |               |                |             |             |
| Pt31              | NoNeg            | Borderline        | 11        | 10         | 52        | 50                  | 8         | 6         | 0                    | 9.67          | T-P           |             | 0                    |                  |               |                |             |             |
| Pt32              | NoNeg            | Borderline        | 11        | 10         | 53        | 51                  | 2         | 6         | 6                    | 10            | ---           |             | 6                    |                  |               |                |             |             |
| Pt33              | NoNeg            | Borderline        | 10        | 10         | 50        | 51                  | 16        | 6         | 2                    | 14.67         | cr sc         |             | 2                    |                  |               |                |             |             |
| Pt34              | NoNeg            | Borderline        | 11        | 10         | 45        | 50                  | 0         | 6         | 5                    | 8             | P             |             | 5                    |                  |               |                |             |             |
| Pt35              | NoNeg            | Borderline        | 10        | 10         | 22        | 47                  | 0         | 6         | 0                    | 14.33         | F-P           |             | 0                    |                  |               |                |             |             |

Table 1. Cont.

| Clinical features |                  | Line Cancellation |            |            |           | Letter Cancellation |           | Wundt-Jastrow |                      | Reading   |               | Personal Neglect |           | Line Bisection |             | Lesion site |
|-------------------|------------------|-------------------|------------|------------|-----------|---------------------|-----------|---------------|----------------------|-----------|---------------|------------------|-----------|----------------|-------------|-------------|
| Group             | Personal Neglect | Severity          | Left (11)  | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6)     | Personal Neglect (9) | Mean (mm) | Right (right) | Personal Neglect | Mean (mm) | Right (right)  | Lesion site |             |
| Pt36              | NoNeg            | No                | Borderline | 11         | 10        | 48                  | 47        | 0             | 1                    | 14.33     | F-T           | 1                | 14.33     | F-T            |             |             |
| Pt37              | NoNeg            | No                | Borderline | 2          | 10        | 51                  | 51        | 0             | 6                    | 20        | T-P           | 1                | 20        | T-P            |             |             |
| Pt38              | NoNeg            | No                | Borderline | 11         | 10        | 50                  | 48        | 2             | 6                    | 16.33     | F-T           | 0                | 16.33     | F-T            |             |             |
| Pt39              | NoNeg            | No                | No         | 11         | 10        | 51                  | 49        | 0             | 6                    | 7.33      | cr sc         | 0                | 7.33      | cr sc          |             |             |
| Pt40              | NoNeg            | No                | No         | 11         | 10        | 52                  | 48        | 0             | 6                    | 10        | ---           | 0                | 10        | ---            |             |             |
| Pt41              | NoNeg            | No                | No         | 11         | 10        | 43                  | 44        | 1             | 6                    | 7.67      | ---           | 0                | 7.67      | ---            |             |             |
| Pt42              | NoNeg            | No                | No         | 11         | 10        | 47                  | 46        | 0             | 6                    | 9.33      | ---           | 0                | 9.33      | ---            |             |             |
| Pt43              | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6                    | 8.67      | ---           | 0                | 8.67      | ---            |             |             |
| Pt44              | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6                    | 7.67      | ic            | 0                | 7.67      | ic             |             |             |
| Pt45              | NoNeg            | No                | No         | 11         | 10        | 50                  | 49        | 0             | 6                    | 11        | ln            | 0                | 11        | ln             |             |             |
| Pt46              | NoNeg            | No                | No         | 11         | 10        | 47                  | 38        |               | 6                    | 8.67      | ---           | 1                | 8.67      | ---            |             |             |
| Pt47              | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6                    | 7.67      | T i cr        | 1                | 7.67      | T i cr         |             |             |
| Pt48              | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6                    | 11        | th            | 0                | 11        | th             |             |             |
| Pt49              | NoNeg            | No                | No         | 11         | 10        | 49                  | 50        | 0             | 6                    | 7.33      | ---           | 1                | 7.33      | ---            |             |             |
| Pt50              | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6                    | 7.67      | sc            | 0                | 7.67      | sc             |             |             |
| Pt51              | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6                    | 8         | F             | 0                | 8         | F              |             |             |
| Pt52              | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6                    | 8         | P             | 1                | 8         | P              |             |             |
| Pt53              | NoNeg            | Yes               | No         | 11         | 10        | 49                  | 50        | 0             | 6                    | 9         | ic th         | 2                | 9         | ic th          |             |             |
| Pt54              | NoNeg            | No                | No         | 11         | 10        |                     |           | 0             | 6                    | 7         | ---           | 0                | 7         | ---            |             |             |
| Pt55              | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6                    | 12.67     | ic            | 0                | 12.67     | ic             |             |             |
| Pt56              | NoNeg            | No                | No         | 11         | 10        | 50                  | 50        | 0             | 6                    | 16.33     | F bg          | 0                | 16.33     | F bg           |             |             |
| Pt57              | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6                    | 13.33     | P             | 0                | 13.33     | P              |             |             |
| Pt58              | NoNeg            | No                | No         | 11         | 10        |                     |           | 0             | 6                    | 16.67     | ---           | 0                | 16.67     | ---            |             |             |
| Pt59              | NoNeg            | Yes               | No         | 11         | 10        | 53                  | 49        | 1             | 6                    | 18.33     | T-P           | 3                | 18.33     | T-P            |             |             |
| Pt157             | NoNeg            | No                | Borderline | 11         | 10        | 36                  | 48        | 1             | 6                    | -14.7     | T-P-O         | 0                | -14.7     | T-P-O          |             |             |
| Pt158             | NoNeg            | No                | Borderline | 11         | 10        | 52                  | 51        | 0             | 5                    | -2.7      | ---           | 0                | -2.7      | ---            |             |             |
| Pt159             | NoNeg            | No                | Borderline | 11         | 10        | 53                  | 51        | 2             | 6                    | -3        | ---           | 0                | -3        | ---            |             |             |
| Pt160             | NoNeg            | Yes               | Borderline | 11         | 10        | 25                  | 51        | 1             | 6                    | 0         | F cr sc       | 4                | 0         | F cr sc        |             |             |
| Pt161             | NoNeg            | Yes               | Borderline | 11         | 10        | 53                  | 51        | 2             | 6                    | -0.3      | T-P           | 2                | -0.3      | T-P            |             |             |
| Pt162             | NoNeg            | Yes               | Borderline | 11         | 10        | 46                  | 51        | 1             | 6                    | 1         | F-T           | 5                | 1         | F-T            |             |             |
| Pt163             | NoNeg            | Yes               | Borderline | 11         | 10        | 37                  | 37        | 11            | 6                    | -0.7      | ---           | 5                | -0.7      | ---            |             |             |
| Pt164             | NoNeg            | No                | Borderline | 11         | 10        | 38                  | 48        | 0             | 6                    | 2.7       | bg            | 1                | 2.7       | bg             |             |             |
| Pt165             | NoNeg            | No                | Borderline | 11         | 10        | 49                  | 48        | 2             | 6                    | -7        | T-P cr ic     | 0                | -7        | T-P cr ic      |             |             |

Table 1. Cont.

| Clinical features |                  | Line Cancellation |            |            |           | Letter Cancellation |           | Wundt-Jastrow |     | Reading   |         | Personal Neglect |  | Line Bisection |          | Lesion site |
|-------------------|------------------|-------------------|------------|------------|-----------|---------------------|-----------|---------------|-----|-----------|---------|------------------|--|----------------|----------|-------------|
| Group             | Personal Neglect | Severity          | Left (11)  | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6)     | (9) | Mean (mm) | (right) |                  |  |                |          |             |
| Pt166             | NoNeg            | No                | Borderline | 11         | 10        | 47                  | 51        | 0             | 6   | 0         | 2.7     |                  |  |                | T-P ic   |             |
| Pt167             | NoNeg            | No                | Borderline | 11         | 10        | 51                  | 46        | 4             | 6   | 0         | -2      |                  |  |                | P cr     |             |
| Pt168             | NoNeg            | Yes               | Borderline | 11         | 10        | 39                  | 51        | 0             | 6   | 2         | 4.7     |                  |  |                | T-P      |             |
| Pt169             | NoNeg            | Yes               | Borderline | 11         | 10        | 53                  | 51        | 2             | 6   | 2         | 5.3     |                  |  |                | ---      |             |
| Pt170             | NoNeg            | No                | Borderline | 11         | 9         | 52                  | 51        | 9             | 6   | 0         | 3       |                  |  |                | ---      |             |
| Pt171             | NoNeg            | No                | No         | 11         | 10        | 22                  | 20        | 0             | 0   | 0         | -35     |                  |  |                | ---      |             |
| Pt172             | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 0         | -17.7   |                  |  |                | th       |             |
| Pt173             | NoNeg            | No                | No         | 11         | 10        | 53                  | 50        | 0             | 6   | 0         | -4.7    |                  |  |                | sc       |             |
| Pt174             | NoNeg            | Yes               | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 2         | -14.7   |                  |  |                | ---      |             |
| Pt175             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 1         | -4      |                  |  |                | ---      |             |
| Pt176             | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 0         | -6.7    |                  |  |                | bg ic    |             |
| Pt177             | NoNeg            | No                | No         | 11         | 10        | 52                  | 47        | 0             | 6   | 0         | -7.7    |                  |  |                | F-T-P sc |             |
| Pt178             | NoNeg            | No                | No         | 11         | 10        | 41                  | 32        | 0             | 6   | 0         | -4.3    |                  |  |                | T-O cr   |             |
| Pt179             | NoNeg            | No                | No         | 11         | 10        | 51                  | 47        | 0             | 6   | 0         | -12.3   |                  |  |                | ---      |             |
| Pt180             | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 0         | -7.3    |                  |  |                | ---      |             |
| Pt181             | NoNeg            | Yes               | No         | 10         | 10        | 34                  | 30        | 0             | 6   | 4         | -4.3    |                  |  |                | ---      |             |
| Pt182             | NoNeg            | No                | No         | 11         | 10        | 52                  | 49        | 0             | 6   | 0         | 0.3     |                  |  |                | po       |             |
| Pt183             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -5.7    |                  |  |                | ---      |             |
| Pt184             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -8.3    |                  |  |                | bg       |             |
| Pt185             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -7.3    |                  |  |                | ---      |             |
| Pt186             | NoNeg            | No                | No         | 11         | 10        | 51                  | 50        | 0             | 6   | 0         | -0.7    |                  |  |                | sc       |             |
| Pt187             | NoNeg            | No                | No         | 11         | 10        | 53                  | 49        | 0             | 6   | 0         | -2.3    |                  |  |                | P ic     |             |
| Pt188             | NoNeg            | No                | No         | 11         | 10        | 47                  | 45        | 0             | 6   | 0         | -2.7    |                  |  |                | F-T      |             |
| Pt189             | NoNeg            | Yes               | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 5         | -6.7    |                  |  |                | ic ln    |             |
| Pt190             | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 0         | -3.7    |                  |  |                | ---      |             |
| Pt191             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -2.3    |                  |  |                | ec       |             |
| Pt192             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -4.7    |                  |  |                | ---      |             |
| Pt193             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -0.3    |                  |  |                | P        |             |
| Pt194             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 0         | -3.3    |                  |  |                | sc       |             |
| Pt195             | NoNeg            | No                | No         | 11         | 10        | 53                  | 51        | 0             | 6   | 1         | -3.3    |                  |  |                | ---      |             |
| Pt196             | NoNeg            | No                | No         | 11         | 10        | 52                  | 51        | 0             | 6   | 1         | -5.7    |                  |  |                | ---      |             |
| Pt197             | NoNeg            | No                | No         | 11         | 10        | 51                  | 51        | 0             | 6   | 0         | -4.7    |                  |  |                | ---      |             |
| Pt198             | NoNeg            | No                | No         | 11         | 10        | 51                  | 51        | 0             | 6   | 0         | -4.3    |                  |  |                | F-T      |             |



**Table 1. Cont.**

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           | Wundt-Jastrow |     | Reading   |             | Personal Neglect |  | Line Bisection |  | Lesion site |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|---------------|-----|-----------|-------------|------------------|--|----------------|--|-------------|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6)     | (9) | Mean (mm) | (right)     |                  |  |                |  |             |
| Pt199             | NoNeg            | No                | 11        | 10         | 49        | 49                  | 0         | 0             | 0   | 1.3       | T           |                  |  |                |  |             |
| Pt200             | NoNeg            | No                | 11        | 10         | 48        | 48                  | 0         | 6             | 0   | -1.3      | ic          |                  |  |                |  |             |
| Pt201             | NoNeg            | No                | 11        | 10         | 41        | 37                  | 0         | 6             | 0   | 0         | bg          |                  |  |                |  |             |
| Pt202             | NoNeg            | No                | 11        | 10         | 52        | 51                  | 0         | 6             | 0   | -12       | T-O ic sc   |                  |  |                |  |             |
| Pt203             | NoNeg            | No                | 10        | 10         | 49        | 47                  | 0         | 6             | 0   | -6.3      | F-P         |                  |  |                |  |             |
| Pt204             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -3.3      | P           |                  |  |                |  |             |
| Pt205             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -1        | cb          |                  |  |                |  |             |
| Pt206             | NoNeg            | No                | 11        | 10         | 53        | 49                  | 0         | 6             | 0   | 3         | cn          |                  |  |                |  |             |
| Pt207             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -2.7      | P cr sc     |                  |  |                |  |             |
| Pt208             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -5.7      | F-P sc      |                  |  |                |  |             |
| Pt209             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -2.7      | ---         |                  |  |                |  |             |
| Pt210             | NoNeg            | Yes               | 10        | 10         | 48        | 50                  | 0         | 6             | 4   | 2.7       | ---         |                  |  |                |  |             |
| Pt211             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -5        | ---         |                  |  |                |  |             |
| Pt212             | NoNeg            | Yes               | 11        | 10         | 47        | 44                  | 0         | 6             | 3   | -5.7      | T-P         |                  |  |                |  |             |
| Pt213             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 3.7       | F ic cr     |                  |  |                |  |             |
| Pt214             | NoNeg            | No                | 11        | 10         | 52        | 51                  | 0         | 6             | 1   | 0.3       | O ic        |                  |  |                |  |             |
| Pt215             | NoNeg            | No                | 11        | 10         | 52        | 51                  | 0         | 6             | 0   | 1.7       | th cr ic sc |                  |  |                |  |             |
| Pt216             | NoNeg            | No                | 11        | 10         | 53        | 48                  | 0         | 6             | 0   | -1        | O sc        |                  |  |                |  |             |
| Pt217             | NoNeg            | Yes               | 11        | 10         | 50        | 49                  | 0         | 6             | 4   | 5         | bg          |                  |  |                |  |             |
| Pt218             | NoNeg            | Yes               | 11        | 10         | 52        | 51                  | 0         | 6             | 2   | 1         | ---         |                  |  |                |  |             |
| Pt219             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -0.7      | ic sc       |                  |  |                |  |             |
| Pt220             | NoNeg            | No                | 11        | 10         | 52        | 49                  | 0         | 6             | 0   | 0         | ---         |                  |  |                |  |             |
| Pt221             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 4.7       | ic          |                  |  |                |  |             |
| Pt222             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -3        | ---         |                  |  |                |  |             |
| Pt223             | NoNeg            | No                | 11        | 10         | 52        | 49                  | 0         | 6             | 0   | 1         | cb          |                  |  |                |  |             |
| Pt224             | NoNeg            | No                | 10        | 10         | 41        | 37                  | 0         | 6             | 0   | 1.7       | P           |                  |  |                |  |             |
| Pt225             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -1        | F-T-P sc    |                  |  |                |  |             |
| Pt226             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -0.3      | ---         |                  |  |                |  |             |
| Pt227             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 0.3       | P           |                  |  |                |  |             |
| Pt228             | NoNeg            | Yes               | 11        | 10         | 53        | 50                  | 0         | 6             | 4   | 0.7       | F-T-P       |                  |  |                |  |             |
| Pt229             | NoNeg            | No                | 11        | 10         | 45        | 42                  | 0         | 6             | 1   | -1.3      | T-P ln      |                  |  |                |  |             |
| Pt230             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -1.3      | po          |                  |  |                |  |             |
| Pt231             | NoNeg            | No                | 11        | 10         | 52        | 51                  | 0         | 6             | 0   | 3         | F-P         |                  |  |                |  |             |

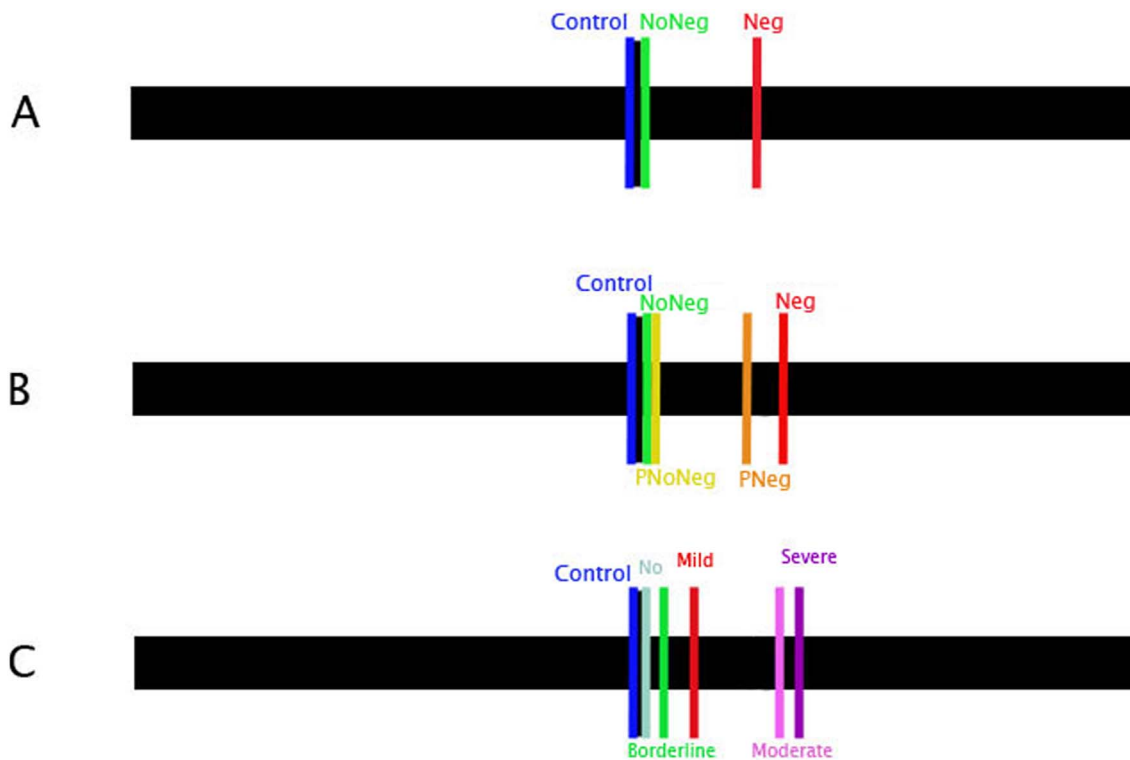
Table 1. Cont.

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           | Wundt-Jastrow |     | Reading   |              | Personal Neglect |  | Line Bisection |  | Lesion site |  |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|---------------|-----|-----------|--------------|------------------|--|----------------|--|-------------|--|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6)     | (9) | Mean (mm) | (right)      |                  |  |                |  |             |  |
| Pt232             | NoNeg            | No                | 11        | 10         | 50        | 49                  | 0         | 6             | 0   | 3.7       | ---          | ---              |  |                |  |             |  |
| Pt233             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 0.3       | sc           | sc               |  |                |  |             |  |
| Pt234             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -7        | ---          | ---              |  |                |  |             |  |
| Pt235             | NoNeg            | No                | 11        | 10         | 52        | 49                  | 0         | 6             | 0   | -1.3      | ---          | ---              |  |                |  |             |  |
| Pt236             | NoNeg            | No                | 11        | 10         | 51        | 47                  | 0         | 6             | 0   | 0         | cn           | cn               |  |                |  |             |  |
| Pt237             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -0.3      | ---          | ---              |  |                |  |             |  |
| Pt238             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 1.3       | po           | po               |  |                |  |             |  |
| Pt239             | NoNeg            | Yes               | 11        | 10         | 51        | 50                  | 0         | 6             | 5   | 6.3       | F-P          | F-P              |  |                |  |             |  |
| Pt240             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 1   | -0.3      | sc           | sc               |  |                |  |             |  |
| Pt241             | NoNeg            | No                | 11        | 10         | 51        | 51                  | 0         | 6             | 0   | 1         | sc           | sc               |  |                |  |             |  |
| Pt242             | NoNeg            | No                | 10        | 9          | 53        | 44                  | 1         | 6             | 0   | 0.7       | F-T-P        | F-T-P            |  |                |  |             |  |
| Pt243             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 0.3       | ---          | ---              |  |                |  |             |  |
| Pt244             | NoNeg            | No                | 11        | 10         | 51        | 49                  | 0         | 6             | 0   | 2         | th           | th               |  |                |  |             |  |
| Pt245             | NoNeg            | Yes               | 11        | 10         | 53        | 51                  | 1         | 6             | 6   | -1.3      | ---          | ---              |  |                |  |             |  |
| Pt246             | NoNeg            | No                | 11        | 10         | 52        | 50                  | 0         | 6             | 0   | -3.3      | sc           | sc               |  |                |  |             |  |
| Pt247             | NoNeg            | No                | 11        | 10         | 52        | 49                  | 0         | 6             | 0   | 4.3       | bg           | bg               |  |                |  |             |  |
| Pt248             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 2.3       | ic put       | ic put           |  |                |  |             |  |
| Pt249             | NoNeg            | No                | 11        | 10         | 49        | 46                  | 0         | 6             | 0   | 4.7       | sc           | sc               |  |                |  |             |  |
| Pt250             | NoNeg            | Yes               | 11        | 10         | 51        | 51                  | 0         | 6             | 2   | 5         | ic ln        | ic ln            |  |                |  |             |  |
| Pt251             | NoNeg            | No                | 11        | 10         | 53        | 50                  | 0         | 6             | 0   | 1         | F            | F                |  |                |  |             |  |
| Pt252             | NoNeg            | No                | 11        | 10         | 53        | 50                  | 0         | 6             | 0   | 0.7       | F-T-P cr     | F-T-P cr         |  |                |  |             |  |
| Pt253             | NoNeg            | No                | 11        | 10         | 53        | 50                  | 0         | 6             | 0   | 3         | F            | F                |  |                |  |             |  |
| Pt254             | NoNeg            | No                | 11        | 10         | 51        | 51                  | 0         | 6             | 0   | 5.3       | ic           | ic               |  |                |  |             |  |
| Pt255             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 4.3       | F-P          | F-P              |  |                |  |             |  |
| Pt256             | NoNeg            | No                | 11        | 10         | 51        | 51                  | 0         | 6             | 0   | 2         | F-T-P        | F-T-P            |  |                |  |             |  |
| Pt257             | NoNeg            | No                | 11        | 10         | 46        | 48                  | 0         | 6             | 0   | 6         | F-T ic cr po | F-T ic cr po     |  |                |  |             |  |
| Pt258             | NoNeg            | No                | 11        | 10         | 50        | 50                  | 0         | 6             | 0   | 4.7       | T cr         | T cr             |  |                |  |             |  |
| Pt259             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | -2.7      | ---          | ---              |  |                |  |             |  |
| Pt260             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 2         | P            | P                |  |                |  |             |  |
| Pt261             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 1         | 6             | 0   | 5.7       | sc           | sc               |  |                |  |             |  |
| Pt262             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 6.3       | F-P-O ic put | F-P-O ic put     |  |                |  |             |  |
| Pt263             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 2.7       | ---          | ---              |  |                |  |             |  |
| Pt264             | NoNeg            | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 0   | 4         | ---          | ---              |  |                |  |             |  |

**Table 1. Cont.**

| Clinical features |                  | Line Cancellation |           |            |           | Letter Cancellation |           | Wundt-Jastrow |           | Reading |     | Personal Neglect |           | Line Bisection |         | Lesion site |  |
|-------------------|------------------|-------------------|-----------|------------|-----------|---------------------|-----------|---------------|-----------|---------|-----|------------------|-----------|----------------|---------|-------------|--|
| Group             | Personal Neglect | Severity          | Left (11) | Right (10) | Left (53) | Right (51)          | Left (20) | Right (6)     | Mean (mm) | (9)     | (6) | (9)              | Mean (mm) | (right)        | (right) | (right)     |  |
| Pt265             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 4.7       | 0       | 6   | 0                | 4.7       | ---            | T       | ---         |  |
| Pt266             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 5.7       | 0       | 6   | 0                | 5.7       | ---            | ---     | ---         |  |
| Pt267             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 4.3       | 0       | 6   | 0                | 4.3       | ---            | ---     | ---         |  |
| Pt268             | No               | No                | 11        | 10         | 52        | 51                  | 1         | 6             | 5.3       | 0       | 6   | 0                | 5.3       | ic             | sc      | ic          |  |
| Pt269             | Yes              | No                | 11        | 10         | 51        | 49                  | 0         | 6             | 3         | 6       | 6   | 6                | 3         | ---            | ---     | ---         |  |
| Pt270             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 3.3       | 0       | 6   | 0                | 3.3       | ---            | ---     | ---         |  |
| Pt271             | No               | No                | 11        | 10         | 53        | 50                  | 0         | 6             | 4         | 0       | 6   | 0                | 4         | ---            | ---     | ---         |  |
| Pt272             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 5.3       | 0       | 6   | 0                | 5.3       | sc             | sc      | sc          |  |
| Pt273             | Yes              | No                | 11        | 10         | 42        | 45                  | 0         | 6             | 3.3       | 3       | 6   | 3                | 3.3       | ic             | sc      | ic          |  |
| Pt274             | No               | No                | 10        | 10         | 47        | 50                  | 0         | 6             | 5.3       | 0       | 6   | 0                | 5.3       | F-T-P          | F-T-P   | F-T-P       |  |
| Pt275             | No               | No                | 11        | 10         | 52        | 51                  | 0         | 6             | 4.7       | 0       | 6   | 0                | 4.7       | sc             | sc      | sc          |  |
| Pt276             | No               | No                | 11        | 10         | 52        | 48                  | 0         | 6             | 4.3       | 0       | 6   | 0                | 4.3       | ---            | ---     | ---         |  |
| Pt277             | No               | No                | 11        | 10         | 50        | 49                  | 0         | 6             | 2         | 0       | 6   | 0                | 2         | P-O            | ic      | P-O         |  |
| Pt278             | Yes              | No                | 11        | 10         | 47        | 47                  | 0         | 6             | 5.7       | 4       | 6   | 4                | 5.7       | po             | po      | po          |  |
| Pt279             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 5.7       | 1       | 6   | 1                | 5.7       | T-P            | sc      | T-P         |  |
| Pt280             | No               | No                | 11        | 10         | 51        | 46                  | 0         | 6             | 6.7       | 0       | 6   | 0                | 6.7       | sc             | sc      | sc          |  |
| Pt281             | No               | No                | 11        | 10         | 53        | 51                  | 0         | 6             | 6         | 0       | 6   | 0                | 6         | i              | th      | i           |  |
| Pt282             | Yes              | No                | 11        | 10         | 24        | 18                  | 0         | 6             | -16.3     | 4       | 6   | 4                | -16.3     | ---            | ---     | ---         |  |

Legend: bg: basal ganglia; cb: caudate nucleus; cn: corona radiata; ec: external capsule; F: frontal lobe; gp: globus pallidus; hth: hypothalamus; i: insula; ic: internal capsule; In: lenticular nucleus; O: occipital lobe; P: parietal lobe; po: pons; put: putamen; sc: sub-cortical; T: temporal lobe; th: thalamus; ---: no radiological report.  
doi:10.1371/journal.pone.0099700.t001



**Figure 1. Means of deviation expressed in mm. in bisecting task for: A. n. 91 Control ( $-0.61 \pm 0.12$ ), n. 157 NoNeg ( $1.59 \pm 7.23$ ) and n. 125 Neg ( $22.4 \pm 21.97$ ) according to the standard battery for assessing hemineglect; B. n. 91 Control ( $-0.61 \pm 0.12$ ), n. 130 NoNeg ( $1.42 \pm 7.13$ ), n. 27 PNoNeg ( $2.44 \pm 7.77$ ), n. 95 PNeg ( $22.25 \pm 21.56$ ) and n. 30 Neg ( $22.86 \pm 23.57$ ) according to the presence/absence of personal neglect; C. n. 91 Control ( $-0.61 \pm 0.12$ ), n. 133 No (NoNeg:  $1 \pm 6.90$ ), n. 24 Borderline ( $5 \pm 8.30$ ), n. 35 Mild ( $11.10 \pm 11.90$ ), n. 46 Moderate ( $21.80 \pm 24.10$ ) and n. 44 Severe ( $32.10 \pm 21.70$ ) according to the severity or absence of neglect.**  
doi:10.1371/journal.pone.0099700.g001

lines was aligned to the patient's head-body midsagittal plane. Patients performed the task in free vision and were instructed not to cover the task stimuli with the right hand, which was holding the pencil. We used lines that were 20 cm long because they are more sensitive than shorter ones [25]. Indeed, bisection of short lines (2 cm) is less sensitive and a paradoxical leftward deviation (cross-over effect) has been found in some patients [26].

## Results

Group means in bisecting the line are reported in Figure 1. Details about means and standard deviations (S.D.) of groups are shown in the legend of Figure 1.

When neglect was assessed using the standard battery for evaluating the hemineglect syndrome [15], 157 patients showed no signs of neglect and 125 showed neglect. Figure 1A reports the means of these groups and the control group's line bisection performance.

We used line bisection performance to determine how many right brain-damaged patients were affected by neglect. We considered patients affected by neglect if their line bisection was  $\geq 6.73$  mm. from the centre of the line (two standard deviations below controls' mean =  $-0.61 \pm 3.67$ ). It emerged that 128 out of 282 patients (45.39%) showed signs of neglect and that the remaining 154 out of 282 patients (54.61%) did not show signs of neglect. Most of the patients found to have neglect on line bisection were also classified as having neglect on the standard battery for hemineglect evaluation [15]; but 31 out of 125 patients (24.8%) assessed as having neglect on line bisection did not show the disorder. On the contrary, 28 out of 157 patients (17.83%)

without neglect showed the presence of the disorder when assessed by line bisection (see Table 2 for details of the patients whose classification changed).

We also investigated the frequency of occurrence of personal neglect in Neg and NoNeg groups classified according to the standard battery for assessing hemineglect. We found that 27 (PNoNeg) out of 157 NoNeg patients (17.20%) showed signs of personal neglect and that 95 (PNeg) out of 125 Neg patients (76 %) were also affected by personal neglect (see Table 3).

To assess differences among groups in line bisection performance, we subdivided our sample by taking into account the presence of personal neglect (see Figure 1B and Figure 2) and performing a one-way ANOVA with Groups (Neg; PNeg; NoNeg; PNoNeg and Controls) as independent variable and deviation from the centre of the line expressed in mm as dependent variable. The analysis showed a significant difference among groups ( $F_{(4,368)} = 52.24$ ;  $p < .01$ ; effect size ( $r$ ) = 0.36) and a post-hoc Scheffé test showed that Controls did not differ from NoNeg ( $p = .84$ ) and PNoNeg ( $p = .88$ ) but differed from Neg and PNeg ( $ps < .01$ ). Neg patients differed from all groups ( $ps < .01$ ) except for PNeg ( $p = ns$ ). Also, PNeg differed from all groups ( $ps < .01$ ) except for Neg ( $p = .99$ ). NoNeg differed only from PNeg and Neg ( $ps < .01$ ). PNoNeg differed significantly only from Neg and PNeg ( $ps < .01$ ).

We also assessed line bisection performance by subdividing the patients according to severity or absence of hemineglect. Their level of impairment was classified on the basis of their performance on the standard battery for evaluating hemineglect. Specifically, we considered "mild" impairment as failure on two out of four

**Table 2.** Clinical data of patients reclassified according to their line bisection performance.

| Patients | Group | Line Cancellation |            | Letter Cancellation |            | Wundt-Jastrow |           | Reading (6) | Personal Neglect (9) | Line Bisection Mean (mm) | Lesion Site |
|----------|-------|-------------------|------------|---------------------|------------|---------------|-----------|-------------|----------------------|--------------------------|-------------|
|          |       | Left (11)         | Right (10) | Left (53)           | Right (51) | Left (20)     | Right (6) |             |                      |                          |             |
| Pt1      | NoNeg | 3                 | 3          | 6                   | 8          | 6             | 6         | 3           | 5                    | -17.5                    | F           |
| Pt2      | NoNeg | 2                 | 10         | 0                   | 12         | 14            | 14        | 4           | 3                    | 1.33                     | F-T         |
| Pt3      | NoNeg | 11                | 10         | 22                  | 50         | 5             | 5         | 5           | 5                    | -8                       | F-T-P i     |
| Pt4      | NoNeg | 8                 | 10         | 1                   | 37         | 1             | 1         | 3           | 6                    | 8.33                     | F-T-P       |
| Pt5      | NoNeg | 11                | 10         | 0                   | 19         | 20            | 20        | 1           | 5                    | -12                      | F-T-P       |
| Pt6      | NoNeg | 11                | 10         | 14                  | 38         | 6             | 6         | 5           | 0                    | -4                       | F-T         |
| Pt7      | NoNeg | 9                 | 10         | 0                   | 20         | 10            | 10        | 6           | 1                    | 0.2                      | F           |
| Pt8      | NoNeg | 7                 | 10         | 0                   | 34         | 9             | 9         | 6           | 4                    | 2.33                     | F-T-P       |
| Pt9      | NoNeg | 11                | 10         | 0                   | 36         | 11            | 11        | 4           | 3                    | 5.67                     | ---         |
| Pt10     | NoNeg | 2                 | 10         | 0                   | 5          | 7             | 7         | 6           | 6                    | 0.33                     | T           |
| Pt11     | NoNeg | 11                | 10         | 32                  | 51         | 6             | 6         | 2           | 0                    | 3                        | ---         |
| Pt12     | NoNeg | 11                | 10         | 0                   | 10         | 20            | 20        | 1           | 0                    | 5.67                     | F-T-P       |
| Pt13     | NoNeg | 9                 | 9          | 40                  | 47         | 11            | 11        | 0           | 0                    | 0                        | Th          |
| Pt14     | NoNeg | 11                | 9          | 33                  | 51         | 12            | 12        | 4           | 0                    | 0                        | F-T-P       |
| Pt15     | NoNeg | 1                 | 10         | 53                  | 49         | 6             | 6         | 6           | 5                    | -6.67                    | Ln          |
| Pt16     | NoNeg | 11                | 10         | 5                   | 50         | 10            | 10        | 6           | 1                    | -3                       | F-T         |
| Pt17     | NoNeg | 11                | 10         | 37                  | 51         | 0             | 0         | 5           | 3                    | -1                       | F-T         |
| Pt18     | NoNeg | 11                | 10         | 4                   | 35         | 9             | 9         | 6           | 6                    | 6                        | F           |
| Pt19     | NoNeg | 11                | 10         | 26                  | 50         | 0             | 0         | 1           | 2                    | 6.33                     | F           |
| Pt20     | NoNeg | 10                | 10         | 39                  | 41         | 9             | 9         | 6           | 4                    | -4.67                    | T-P         |
| Pt21     | NoNeg | 7                 | 11         | 36                  | 41         | 1             | 1         | 6           | 3                    | 1.33                     | ---         |
| Pt22     | NoNeg | 11                | 10         | 44                  | 51         | 3             | 3         | 6           | 2                    | 5.33                     | lc          |
| Pt23     | NoNeg | 10                | 10         | 0                   | 43         | 5             | 5         | 6           | 4                    | 1                        | F-T-P       |
| Pt24     | NoNeg | 11                | 10         | 44                  | 47         | 0             | 0         | 5           | 0                    | 3.33                     | ---         |
| Pt25     | NoNeg | 11                | 10         | 41                  | 44         | 3             | 3         | 6           | 2                    | 5                        | ic th       |
| Pt26     | NoNeg | 10                | 10         | 9                   | 45         | 0             | 0         | 0           | 2                    | -3.67                    | T-P-O       |
| Pt27     | NoNeg | 11                | 10         | 50                  | 51         | 2             | 2         | 2           | 4                    | 5.67                     | F-T         |
| Pt28     | NoNeg | 11                | 10         | 20                  | 50         | 2             | 2         | 6           | 0                    | 4.67                     | F-T-P ic    |
| Pt29     | Neg   | 11                | 10         | 32                  | 50         | 0             | 0         | 6           | 3                    | 12.33                    | F           |
| Pt30     | Neg   | 11                | 10         | 45                  | 51         | 1             | 1         | 6           | 1                    | 10.33                    | F-T         |
| Pt31     | Neg   | 11                | 10         | 52                  | 50         | 8             | 8         | 6           | 0                    | 9.67                     | T-P         |
| Pt32     | Neg   | 11                | 10         | 53                  | 51         | 2             | 2         | 6           | 6                    | 10                       | ---         |
| Pt33     | Neg   | 10                | 10         | 50                  | 51         | 16            | 16        | 6           | 2                    | 14.67                    | cr sc       |
| Pt34     | Neg   | 11                | 10         | 45                  | 50         | 0             | 0         | 6           | 5                    | 8                        | P           |

**Table 2. Cont.**

| Patients | Group | Line Cancellation |            | Letter Cancellation |            | Wundt-Jastrow |       | Reading (6) | Personal Neglect (9) | Line Bisecting Mean (mm) | Lesion Site |
|----------|-------|-------------------|------------|---------------------|------------|---------------|-------|-------------|----------------------|--------------------------|-------------|
|          |       | Left (11)         | Right (10) | Left (53)           | Right (51) | Left (20)     | Right |             |                      |                          |             |
| Pt35     | Neg   | 10                | 10         | 22                  | 47         | 0             | 0     | 6           | 0                    | 14.33                    | F-P         |
| Pt36     | Neg   | 11                | 10         | 48                  | 47         | 0             | 1     | 1           | 1                    | 14.33                    | F-T         |
| Pt37     | Neg   | 2                 | 10         | 51                  | 51         | 0             | 1     | 6           | 1                    | 20                       | T-P         |
| Pt38     | Neg   | 11                | 10         | 50                  | 48         | 2             | 0     | 6           | 0                    | 16.33                    | F-T         |
| Pt39     | Neg   | 11                | 10         | 51                  | 49         | 0             | 0     | 6           | 0                    | 7.33                     | cr sc       |
| Pt40     | Neg   | 11                | 10         | 52                  | 48         | 0             | 0     | 6           | 0                    | 10                       | ---         |
| Pt41     | Neg   | 11                | 10         | 43                  | 44         | 1             | 0     | 6           | 0                    | 7.67                     | ---         |
| Pt42     | Neg   | 11                | 10         | 47                  | 46         | 0             | 0     | 6           | 0                    | 9.33                     | ---         |
| Pt43     | Neg   | 11                | 10         | 53                  | 51         | 0             | 0     | 6           | 0                    | 8.67                     | ---         |
| Pt44     | Neg   | 11                | 10         | 53                  | 51         | 0             | 0     | 6           | 0                    | 7.67                     | Ic          |
| Pt45     | Neg   | 11                | 10         | 50                  | 49         | 0             | 0     | 6           | 0                    | 11                       | Ln          |
| Pt46     | Neg   | 11                | 10         | 47                  | 38         |               | 1     | 6           | 1                    | 8.67                     | ---         |
| Pt47     | Neg   | 11                | 10         | 52                  | 51         | 0             | 1     | 6           | 1                    | 7.67                     | T i cr      |
| Pt48     | Neg   | 11                | 10         | 52                  | 51         | 0             | 0     | 6           | 0                    | 11                       | th          |
| Pt49     | Neg   | 11                | 10         | 49                  | 50         | 0             | 1     | 6           | 1                    | 7.33                     | ---         |
| Pt50     | Neg   | 11                | 10         | 53                  | 51         | 0             | 0     | 6           | 0                    | 7.67                     | Sc          |
| Pt51     | Neg   | 11                | 10         | 53                  | 51         | 0             | 0     | 6           | 0                    | 8                        | F           |
| Pt52     | Neg   | 11                | 10         | 52                  | 51         | 0             | 1     | 6           | 1                    | 8                        | P           |
| Pt53     | Neg   | 11                | 10         | 49                  | 50         | 0             | 2     | 6           | 2                    | 9                        | ic th       |
| Pt54     | Neg   | 11                | 10         | ---                 | ---        | 0             | 0     | ---         | 0                    | 7                        | ---         |
| Pt55     | Neg   | 11                | 10         | 52                  | 51         | 0             | 0     | 6           | 0                    | 12.67                    | Ic          |
| Pt56     | Neg   | 11                | 10         | 50                  | 50         | 0             | 0     | 6           | 0                    | 16.33                    | F bg        |
| Pt57     | Neg   | 11                | 10         | 53                  | 51         | 0             | 0     | 6           | 0                    | 13.33                    | P           |
| Pt58     | Neg   | 11                | 10         | ---                 | ---        | 0             | 0     | 6           | 0                    | 16.67                    | ---         |
| Pt59     | Neg   | 11                | 10         | 53                  | 49         | 1             | 3     | 6           | 3                    | 18.33                    | T-P         |

Legend: bg: basal ganglia; cr: corona radiata; F: frontal lobe; i: insula; ic: internal capsule; In: lenticular nucleus; O: occipital lobe; P: parietal lobe; sc: sub-cortical; T: temporal lobe; th: thalamus.  
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Table 3. Clinical Data.

| Group           | Line Cancellation |             | Letter Cancellation |               | Wundt-Jastrow |             | Sentence Reading |             | Personal Neglect |  |
|-----------------|-------------------|-------------|---------------------|---------------|---------------|-------------|------------------|-------------|------------------|--|
|                 | Left (11)         | Right (10)  | Left (53)           | Right (51)    | Left (0)      | Right (0)   | (6)              | (9)         |                  |  |
| Neg (n = 30)    | 7.57 (4.75)       | 9.10 (1.71) | 16.29 (17.11)       | 33.46 (16.48) | 9.17 (6.56)   | 0.62 (1.57) | 2.93 (2.56)      | 0.37 (0.49) |                  |  |
| PNeg (n = 95)   | 6.52 (4.62)       | 9.15 (1.84) | 11.83 (17.07)       | 30.57 (16.69) | 9.35 (6.58)   | 0.83 (2.19) | 2.42 (2.30)      | 4.32 (1.64) |                  |  |
| PNoNeg (n = 27) | 10.89 (0.33)      | 10 (0)      | 46 (8.76)           | 47.41 (7.72)  | 1.37 (3.69)   | 1.41 (3.68) | 6 (0)            | 3.67 (1.41) |                  |  |
| NoNeg (n = 130) | 10.89 (0.81)      | 9.98 (0.12) | 50.69 (4.80)        | 49.20 (4.01)  | 0.26 (1.15)   | 0.16 (0.85) | 5.95 (0.46)      | 0.12 (0.32) |                  |  |

Maximum scores on paper/pencil tests. Table reports means and (S.D.).

Neg = Neglect patients; PNeg = Neglect patients also suffering from personal neglect; PNoNeg = patients without neglect but with personal neglect; NoNeg = patients with no signs of neglect  
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tests, “moderate” as failure on three out of four tests and “severe” impairment as failure on all tests. Further, we classified as “borderline” patients who failed on one out of the four tests and as “No Neg” patients who performed flawlessly (see Figure 1C). For this purpose, we performed a one-way ANOVA with Groups (Severe, Moderate, Mild, Borderline and No Neg) as independent variable and deviation from centre of the line expressed in mm as dependent variable. The analysis showed a significant difference among groups ( $F_{(4,277)} = 45.77$ ;  $p < .001$ ; effect size ( $r = 0.40$ ) and a post-hoc Scheffé Test showed that the Severe and Moderate groups were significantly worse than the other groups ( $p < .05$ ), whereas the Mild group differed from the Severe, Moderate and No Neg ( $p < .05$ ) groups but not from the Borderline ( $p = .64$ ) group. Differently, the Borderline group differed significantly from the Severe and Moderate ( $p < .001$ ) groups but not from the Mild and No Neg ( $ps = .82-.64$ ) groups.

We also performed Pearson’s correlation on the Neg Group tests and found that personal neglect, measured by the Use of Common Objects did not correlate with the reading test (errors on the left of the single words), with the Wundt-Jastrow Area Illusion Test (unexpected left responses) and line bisection (deviations from the centre expressed in mm) but that the other tests correlated with each other (see Table 4 for details).

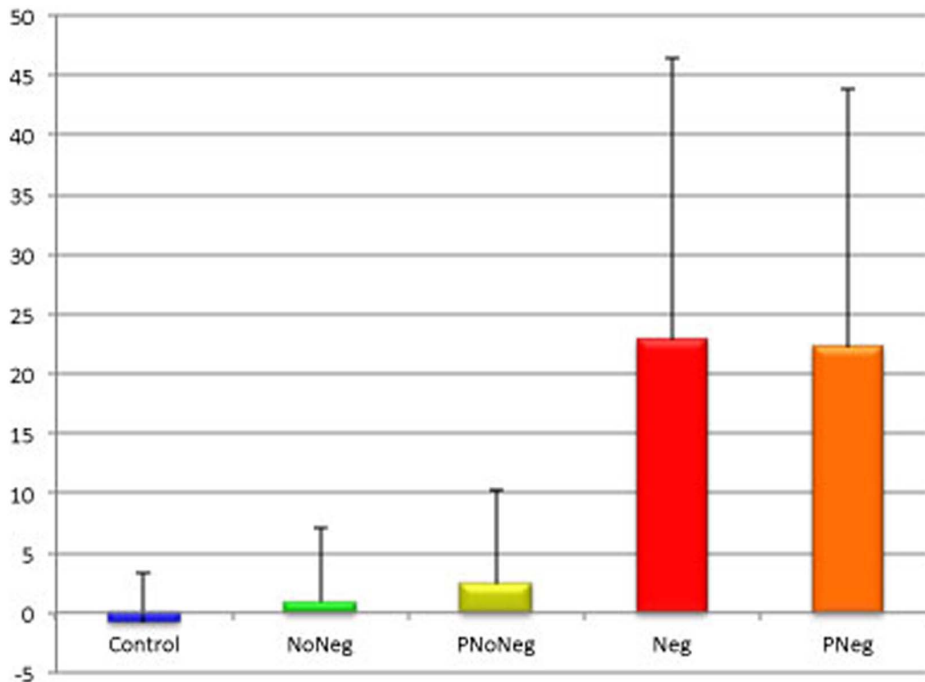
## Discussion

In the present study 45.39% of the chronic right brain-damaged patients showed neglect on the standard battery for hemineglect and the remaining 54.61% showed no signs of neglect.

We found that the line bisection task correlates with other paper and pencil tests commonly used to investigate the presence of hemineglect but not with personal neglect evaluation tasks. The presence of personal neglect seemed to be unrelated to the patients’ bisecting behaviour. This is in line with Azouvi et al. [25], who found few correlations between extrapersonal and personal neglect, and supports the presence of dissociable clinical phenomena in different spatial domains [27] [28] [29]. Furthermore, the independence of personal neglect from line bisection behaviour is also supported by evidence that patients with neglect and without personal neglect bisected the line more to the right than patients with neglect in extrapersonal and personal space. Taking into account the severity of neglect, we found that patients with severe and moderate neglect deviated significantly from the middle of the line with respect to patients with mild and no neglect. One interesting result of our investigation is that 59 patients (approximately 20% of the whole sample of right brain-damaged patients) who did or did not show the presence of hemineglect in bisecting the line contrasted the original diagnosis made using the standard battery for hemineglect. This finding provides further evidence that a combination of different tasks (e.g. line bisection, cancellation tasks and reading) is necessary to detect spatial neglect and its different manifestations [30] [31].

Previous studies [32] [33] also described patients with deficits on the line bisection task but not on the cancellation task (and vice versa); but, as in our study, overall patient performance on both tasks seemed to be correlated [33].

Rorden et al. [34] found that patients who have problems on the line bisection task have more posterior lesions (temporo-occipital junction) than patients who fail on the target cancellation task (superior temporal gyrus). Different studies also showed that the shift is more marked in neglect patients with damage in the posterior rather than the middle cerebral artery territory [25] [32] [35]. Furthermore, in a recent study Molenberghs & Sale [36] reported that patients with a lesion in the angular gyrus performed



**Figure 2. Means and standard deviations of Control, NoNeg, PNoNeg, PNeg and Neg in bisecting task.**  
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deficiently on both the line bisection and the cancellation task. In Molenberghs et al.'s [3] recent meta-analysis, the authors reported that most of the lesions associated with line bisection deficits are located more posteriorly than those associated with target cancellation deficits. We observed the lesions of our patients who failed or not on line bisection, but were unable to draw any conclusions because the lesions were large (also involving anterior areas) both when they showed neglect only in line bisection and when they did not. It should also be noted that patients 1 and 2, who were classified as severe (i.e., they failed on four out of four tests of the hemineglect battery) did not deviate from the centre of the line during bisection and that 12 patients (i.e., from 3–14) with moderate neglect (i.e., they failed on three out of four tests of the hemineglect battery) were considered not to have neglect on line bisection. Nevertheless, one limit of our study was the lack of a visual field exam that could have helped us understand whether patients were or were not affected by hemianopia. Indeed,

previous studies [35] [37] [38] [39] demonstrated that neglect patients with concomitant hemianopia bisected more rightward than patients with neglect without visual field defects and differed from patients with only hemianopia [40] [41] who, compared with healthy controls, bisected with small but significant ipsilesional deviations towards the intact hemifield. The same result is obtained when healthy subjects are asked to simulate hemianopia [42], but the differences are more marked in the patients depending on the time since stroke. As demonstrated by Saj et al. [43], in patients with recent stroke and neglect, hemianopia aggravates the visual-spatial deviation. Furthermore, acute hemianopia may induce visual-neglect-like behaviour also in patients without neglect [43]. In our study, however, patients were chronic (mean distance from onset = 209.30 ± 392.39 days) and it has been demonstrated that the influence of hemianopia disappears relatively quickly over time due to compensation [43]. Another limit of our study is the difference in the onset for Neg and NoNeg

**Table 4. Pearson correlations.**

|                  | Left Barrage | Left H   | Left WJ  | Reading  | Personal Neglect | Line Bisection |
|------------------|--------------|----------|----------|----------|------------------|----------------|
| Left Barrage     | 1            | 0.460**  | -0.467** | 0.480**  | -0.321**         | -0.511**       |
| Left H           | 0.460**      | 1        | -0.341** | 0.399**  | -0.217*          | -0.367**       |
| Left WJ          | -0.467**     | -0.341** | 1        | -0.364** | 0.124            | 0.437**        |
| Reading          | 0.480**      | 0.399**  | -0.364** | 1        | -0.156           | -0.501**       |
| Personal Neglect | -0.321**     | -0.217*  | 0.124    | -0.156   | 1                | 0.099          |
| Line Bisection   | -0.511**     | -0.367** | 0.437**  | -0.501** | 0.099            | 1              |

\*\*p<0,01.

\*p<0,05.

Table reports correlations on the left side hits for each test of the neglect battery.

Left Barrage = Left Line Cancellation Test; Left H = Left Letter Cancellation Test; Left WJ = Left unexpected responses on Wundt-Jastrow Area Illusion Test; Reading = Sentence Reading; Personal Neglect = performance on Use of Common objects; Line Bisection = Left Deviation on the Line Bisection Task.

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groups. Indeed, it is possible that in NoNeg patients the longer onset ( $639.80 \pm 1602.68$  days) could have influenced their performance and we cannot exclude that in this group some patients had already recovered from neglect. In some respects line bisection may be more sensitive than other cancellation tasks in detecting signs of neglect in these patients because it is less prone to the rehabilitation process and therefore might partially account for the differentiation in our sample's classification when performance was assessed only by means of the line bisection task.

For the above mentioned reasons, the nature of the spatial disorders of patients who fail on just one test is controversial and not easy to interpret. According to the results reported here, using

batteries with several tests guarantees greater sensitivity of diagnoses and better planning of subsequent rehabilitation.

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## Author Contributions

Conceived and designed the experiments: PG LP. Performed the experiments: AM. Analyzed the data: PG LP. Wrote the paper: PG LP AM.

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