A battery of tests for the quantitative assessment of unilateral neglect

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Abstract. Purpose: The lack of agreement regarding assessment methods is responsible for the variability in the reported rate of occurrence of unilateral neglect (UN) after stroke. In addition, dissociations have been reported between performance on traditional paper-and-pencil tests and UN in everyday life situations.

Methods: In this paper, we present the validation studies of a quantitative test battery for UN, including paper-and-pencil tests, an assessment of personal neglect, extinction, and anosognosia, and a behavioural assessment, the Catherine Bergego Scale (CBS). The battery was given to healthy subjects (n = 456 – 476) and to patients with subacute stroke, either of the right or the left hemisphere.

Results: In healthy subjects, a significant effect of age, education duration and acting hand was found in several tasks. In patients with right hemisphere stroke, the most sensitive paper and pencil measure was the starting point in the cancellation task. The whole battery was more sensitive than any single test alone. An important finding was that behavioural assessment was more sensitive than any other single test. Neglect was two to four times less frequent, but also less severe and less consistent after left hemisphere stroke.

Conclusion: Assessment of UN should rely on a battery of quantitative and standardised tests. Some patients may show clinically significant UN in everyday life while obtaining a normal performance on paper-and-pencil measures. This underlines the necessity to use a behavioural assessment of UN.

Keywords: Unilateral neglect, assessment, stroke

1. Introduction: why a quantitative test battery for unilateral neglect?

Unilateral neglect (UN) is a failure to attend to the contralesional side of space. It is a puzzling disorder commonly encountered after stroke, particularly of the right hemisphere. The study of UN is of con-
siderable interest for neuroscientists interested in spatial cognition or attention [38]. However, UN also has major practical significance for clinicians and rehabilitation professionals dealing with stroke patients. Indeed, UN may affect many daily living skills and has been found associated with poor functional recovery from stroke. Denes et al. [30] found that neglect was the worst prognostic factor for functional recovery in hemiplegia, when compared to other cognitive disorders, such as aphasia, intellectual deterioration, or disturbed emotional reactions. These findings have been subsequently largely reproduced by other authors, who showed that neglect had an adverse influence upon functional outcome, improvement on rehabilitation, length of hospital stay and discharge to home [2, 3, 25, 45, 53], although contradictory results have been reported [35, 54].

In most severe cases, after a large right hemisphere stroke, UN is obvious and can be detected by simple observation of the patient in his bed. However, in most patients, UN is not clinically apparent and specific testing is needed to reveal the disorder. Specific testing is also necessary to give objective measures of the severity of neglect and to monitor recovery during rehabilitation. However, objective assessment of neglect is not easy, for at least two reasons. Firstly, it is now widely accepted that UN is not, at least from a clinical point of view, a unitary disorder [14]. Clinical manifestations of UN may vary from one patient to the other, and in a given patient, according to time and nature of assessment. The different clinical manifestations of UN, that can dissociate one from each other, include viewer- or object-centred neglect, neglect for near or far extrapersonal space, personal neglect, representational neglect, motor neglect, directional hypokinesia [43]. However, most commonly used tests only take into account visual or visuo-motor aspects of UN in the near peripersonal space [42]. Secondly, UN is not an all-or-nothing phenomenon. Neglect can vary in a given patient according to the test used, its nature, its complexity, but also according to extraneous factors, such as fatigue, motivation, or mood status.

**Assessment of UN.** A great number of clinical tests of UN have been reported in the literature. However, despite a large amount of research, there is still no consensus among clinicians regarding the methods of identifying neglect and monitoring changes after treatment [22, 59]. A recent review [51] identified 62 assessment tools for UN. Only 28 of them were standardised, thus allowing objective quantified measurement of the disorder. In a recent systematic review of published reports, Bowen et al. [22] found that the frequency of occurrence of neglect in patients with right brain damage ranged from 13% to 82%. The assessment method used was one of the main factors explaining the discrepancies between the different studies. Thirty studies were included in this latter review, most of them using a battery of paper-and-pencil tests. Only one study [46] did not specify how UN was assessed. Nineteen studies used a battery of up to 7 different tests. The most frequently used single task was a cancellation task. Figure copying was also commonly used. Only occasionally did the assessment of UN involve an ecological assessment of neglect in everyday life.

Many clinicians are familiar with several simple bedside screening tests, such as object copying [33, 52], or drawing. However, such tests are not very sensitive and are difficult to score in a quantitative way. Cancellation tasks are more sensitive and may give quantitative scores. There are several versions, but all of them require the patient to find and cancel target items displayed on an A4 paper sheet. In the classical line cancellation task [1], there are no distractor, only lines to cancel. In most other tests, such as the bells test [34], or the star cancellation test [71], distractors are mixed with targets in a pseudo-random fashion, thus improving the sensitivity of the task. Line bisection is another widely used test. Patients with UN tend to show a rightward deviation of the subjective midpoint [64]. The sensitivity of line bisection depends on the length of the line to bisect, longer lines being more sensitive [16]. With short lines, neglect patients show a paradoxical leftward deviation (“crossover effect”) [39]. Other clinical tests have been proposed, such as the overlapping figures test [32], in which patients are asked to name four overlapping figures, two on the right and two on the left of a fifth centrally located figure, and reading and writing tasks. These different tests assess visual or visuo-motor aspects of UN in the close peripersonal space. Personal neglect can be assessed by asking the patient to comb his hair, shave or put on make-up [15, 50, 73], or to reach his left arm with his right hand [18].

The Fluff test has been recently proposed as a simple test for studying personal neglect [27]. This latter test requires patients to remove, with one’s eyes closed, 24 2-cm diameter circles attached with velcro to the front of their clothes. Neglect in the far extrapersonal space can be assessed by requiring a patient to describe objects in the room around him, or to bisect lines or cancel items located outside hand reach, for example with a laser pointer [40]. However, these tests cannot easily be replicated across different settings. Repre-
sentational neglect is addressed by asking the patient to describe from memory a familiar place [17], although such a procedure cannot be scored quantitatively. Rode and Perenin [61] devised a simple test that permits to obtain a quantitative score of representational neglect for French patients. Patients have to generate a mental image of the map of France and to cite as many cities they can mentally visualize on the right and the left of an imaginary line. Motor neglect is usually observed by therapists who remark the lack of spontaneous use of the contralesional limb. However, there is no simple way to quantitatively score motor neglect or directional hypokinesia in a routine clinical setting. A few standardised assessment batteries including various clinical tests have been published. The Behavioural Inattention Test (BIT) [37,71] is a comprehensive and well validated one, including both paper and pencil and behavioural tests.

**Ecological assessment of UN.** Although paper-and-pencil tests are useful for rapid clinical screening, they fail to consider the patient’s actual performance in his everyday life. Some patients obtain a normal performance on conventional tests, while showing a directional bias in daily life skills. Such dissociations have been attributed to the relative sparing of voluntary orientation of attention (involved in conventional tests) contrasting with an impairment of automatic orienting which allows attention to be automatically captured by relevant stimuli in everyday life [10,65]. There is a need for standardised ecological measures of neglect to quantify the extent of neglect in everyday life, to adapt rehabilitation to the individual patient’s limitations, to monitor changes and to assess the effectiveness of rehabilitation. This last point is of great importance for rehabilitation. This battery demonstrated good inter-rater and test-retest reliability. However, it did not seem to be more sensitive than paper-and-pencil tests. An Italian team has devised a semi-structured scale of both personal and extrapersonal neglect [56,72,73]. Extrapersonal neglect is assessed by asking the patients to serve tea or to distribute cards to four persons around a square table, to describe complex figures and objects in a room. Personal neglect is assessed by requiring to use common objects (razor or powder, comb, glasses). Inter-rater reliability is good [72]. Only extrapersonal subtests were significantly correlated with paper-and-pencil tests. A modified version of the personal subscale has been proposed, the comb and razor test, with a more precise quantitative scoring system [15,50]. The Baking Tray Task consists of 16 wooden cubes, that the patient is required to place as evenly as possible over a 75 × 100 cm board, “as if they were buns on a baking tray” [68]. Patients with UN tend to place the cubes preferentially on the right part of the board.

Although these different tasks are all simulations of real-life situations, they do not provide any objective information on the patient’s behaviour in his actual everyday environment. Most of these ecological tests still represent quite artificial situations which may rely more on voluntary rather than automatic orienting of attention. Moreover, they do not take into account anosognosia. Considering the above mentioned limitations and difficulty of assessment of UN, a collaborative study was decided in the French-speaking community, with the objective to design and validate a test battery of UN, that could be both psychometrically sound and easy to complete within a rehabilitation setting. This battery (“Batterie d’évaluation de la négligence spatiale”, BEN) comprises two different parts. The first one includes traditional clinical and “paper and pencil” tests of neglect and related disorders, the second one is a standardised observational scale, aimed at providing an ecological assessment of neglect in the patient’s everyday life.

**2. Paper-and pencil tests of the French test battery for UN (“Batterie d’évaluation de la négligence spatiale”, BEN)***

**2.1. Materials and methods**

**2.1.1. Subjects**

As a first step, normative data were collected in a group of healthy individuals (n = 456 to 576 depend-
The objective was to determine norms and a pathological threshold for each task, and to assess the effect on performance of five factors: gender; age (four age groups: 20–34; 35–49; 50–64; 65–80); education duration (≤8 years; 9–12 years; ≥13 years); handedness; and acting hand (half of the subjects performed the task with their preferred hand, half of them with their non-dominant hand).

Two groups of patients were included, at the subacute stage after a stroke either in the right ($n = 206$) [6] or the left ($n = 89$) [11] hemisphere. For patients with left hemisphere stroke, only non-verbal subtests were given, to control for any confounding effect of associated language impairments. Nevertheless, 11 patients with left hemisphere stroke were excluded from the study due to severe aphasia with major comprehension deficits. The main characteristics of the two groups are displayed on Table 1. It appeared that, as compared to the general stroke population, these patients were relatively younger, probably due to a selection bias related to the fact that most of them were recruited through specialised stroke rehabilitation units, and not from geriatric wards. These patients should be regarded as representative of stroke patients referred to a rehabilitation facility. Not surprisingly, the majority of patients also had motor deficits (hemiparesis or hemiplegia). Severity of motor impairments (which reflects overall stroke severity) was assessed with a four-level scale, ranging from 0 (no motor deficit) to 3 (severe hemiplegia). The amount of patients with severe hemiplegia was quite similar in both groups (see Table 1). In addition, patients were classified in four groups according to stroke localisation (anterior; posterior; antero-posterior; subcortical) as assessed with CT and/or MRI scans by examiners blind to neuropsychological assessment. Anatomic data were not available for 49 patients in the right hemisphere group and for seven patients in the left hemisphere group.

### 2.1.2. Methods: Paper-and-pencil tests of the BEN

Most of paper-and-pencil tests included in the battery were adapted from the existing literature, with their authors’ permission. In addition to these traditional tests, personal UN and related disorders, such as anosognosia and extinction were also addressed.

#### 2.1.2.1. Paper-and-pencil tests of extrapersonal neglect

**The bells test** [34]. Subjects were asked to circle 35 targets (black-ink drawings of bells), presented on a horizontal A4 paper sheet, along with 280 distractors in a pseudo-random array. The total number of omissions and the difference between left- and right-sided omissions were recorded. In addition, a special care was given to identifying the subject’s starting point. Targets were equally distributed in seven columns (three left, three right, and one central) numbered from 1 to 7 starting from the left. The starting point was operationally defined as the number (1–7) of the column including the first circled bell.

**Figure copying** [33,52]. Subjects were asked to copy on a horizontal A4 sheet a drawing including (from the left to the right) a tree, a fence, a house with a left-sided chimney, and a second tree. Following Ogden [52], a five-level scale was used, ranging from 0 (no omission) to 4 (omission of the left tree and of at least the left part of another item).

**Clock drawing.** Patients were required to place the 12 hours in a circle drawn by the examiner. A three-level scale was used, with a score of 0 in case of a normal symmetrical performance, of 1 in case of omissions of a part of left-sided hours and of 2 in case of omission or rightward displacement of all left-sided hours.

**Line bisection.** Patients were asked to mark the middle of four lines of two different lengths (5-cm and 20-cm), presented separately centred on an A4 horizontal sheet. Deviation from the true middle was measured in mm, positively for rightward deviation, negatively for leftward deviation.

**Overlapping Figures Test** [32]. Test stimuli consisted of two figures overlapping on the right and two on the left side of a card, all of them overlapping a fifth centrally located figure. Patients were asked to name all the figures they could detect. The total number of omitted figures, and the difference between left- and right-sided omissions across five trials were recorded.

**Reading** [70]. Patients were asked to read a short 12-line text, horizontally printed on an A4 sheet. The total
Table 2
Performance of healthy controls on the BEN (adapted from Rousseaux et al., 2001)

<table>
<thead>
<tr>
<th>Test variables</th>
<th>Maximal possible score</th>
<th>Mean (SD)</th>
<th>Range</th>
<th>Percentile 5/95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bells test (n = 576)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omissions (total number)</td>
<td>35</td>
<td>2.06 (1.49)</td>
<td>0 / 10</td>
<td>0 / 6</td>
</tr>
<tr>
<td>Omissions (left minus right)</td>
<td>15</td>
<td>-0.05 (1.39)</td>
<td>-6 / 5</td>
<td>-2 / 2</td>
</tr>
<tr>
<td>Starting point</td>
<td>7</td>
<td>1.88 (1.49)</td>
<td>1 / 7</td>
<td>1 / 5</td>
</tr>
<tr>
<td>Figure copying (n = 487)</td>
<td>4</td>
<td>0.04 (0.21)</td>
<td>0 / 2</td>
<td>0 / 0</td>
</tr>
<tr>
<td>Clock drawing (n = 457)</td>
<td>2</td>
<td>0.01 (0.09)</td>
<td>0 / 1</td>
<td>0 / 0</td>
</tr>
<tr>
<td>Bisection (mm) (n = 457)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-cm lines</td>
<td>100</td>
<td>-0.95 (4.15)</td>
<td>-16 / 15</td>
<td>-7.2 / 6.5</td>
</tr>
<tr>
<td>5-cm lines</td>
<td>25</td>
<td>-0.17 (1.45)</td>
<td>-7 / 5</td>
<td>-2.5 / 2</td>
</tr>
<tr>
<td>Text reading (n = 457)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omissions (total number)</td>
<td>0.04 (0.26)</td>
<td>0 / 3</td>
<td>0 / 0</td>
<td></td>
</tr>
<tr>
<td>Omissions (left minus right)</td>
<td>0.02 (0.26)</td>
<td>-1 / 3</td>
<td>0 / 0</td>
<td></td>
</tr>
<tr>
<td>Writing (left margin, cm) (n = 456)</td>
<td>3.0 (2.54)</td>
<td>0 / 25</td>
<td>0.79 / 7.72</td>
<td></td>
</tr>
</tbody>
</table>

number of words omitted, and the difference between left- and right-sided omissions within the first five lines were recorded.

Writing. Patients were asked to write, on three separate lines, their first and last names, address, and profession (or the current date if they had no profession). The score was the maximal left margin width (in cm).

2.1.2.2. Assessment of gaze orientation and personal neglect
Spontaneous gaze and head orientation was assessed with a four-level scale [60] ranging from 0: no deviation, to 3: permanent rightward deviation of gaze and head.

Personal neglect was assessed following Bisiach et al. [18] methodology. Patients were asked to reach their left hand with the right hand, first with eyes open, then with eyes closed. A four-level scale was used, ranging from 0: normal performance, to 3: no attempt to reach the target.

2.1.2.3. Assessment of related disorders
Awareness of motor and visual deficits was assessed following Bisiach et al. methodology [19], using a four-level scale, both for motor and visual impairments (range: 0 = perfect awareness to 3 = the patient never admitted having some impairment, despite its demonstration by the examiner).

Visual extinction and hemianopia were tested clinically by wiggling fingers for two seconds in one or both visual fields (six trials). Extinction was considered as present when a patient failed at least once to report a contralesional stimulus during bilateral simultaneous presentation, while accurately detecting unilateral stimuli.

2.2. Results

2.2.1. Performance of healthy controls
Some tasks showed a ceiling effect due to a nearly perfect performance: clock drawing, overlapping figures, reading, head and gaze deviation, personal neglect, and visual extinction. For these tasks, any deviation from optimal performance should be considered as abnormal. The other tasks showed a more variable pattern of performance, allowing the determination of a pathological threshold that was arbitrary set below the fifth percentile of the control group. The main results of the performance of the control group are displayed in Table 2.

There was no significant effect of gender, for any task. However, performance in several tasks appeared to be significantly affected by age, education, and by the acting hand [62]. In the bells test, the total number of omissions was significantly higher in older or less educated people. The difference between left and right omissions was also significantly associated with education (more left-sided omissions for lower education levels and more right-sided omissions for higher education duration). Although only a minority of subjects showed one omission in the Figure copying test, the effect of education was significant, due to less omissions in the highest education group. There was a mild, but significant, leftward deviation in line bisection. This deviation was significantly influenced by the acting hand (larger leftward deviation with the left hand), but only for short lines (5-cm). Other factors, including age, gender or handedness, had no significant influence on performance in line bisection. Finally, the left margin in the writing test was significantly larger in older persons, when using the left hand or in left-handers.
2.2.2. Patients with right hemisphere stroke

The main result was that test sensitivity greatly varied from one test to another (Table 3) [6]. The amount of patients with neglect on each individual subtest ranged from 19.0% to 50.5%. However, more than 85% of patients showed UN on at least one test. The two most sensitive tests were the bells test and the reading test. In the bells test, the most sensitive measure was not the number of omissions, but rather the spatial location of the starting point spontaneously used by the patient. While 80% of controls used a left to right scanning strategy, a majority of patients used a reverse pattern, starting with a right-sided target (Fig. 1).

In the line bisection test, a length effect was found. Indeed, longer lines (20-cm) were nearly twice as sensitive than shorter (5-cm) ones. Bisection of short lines was the less sensitive test in the battery. A paradoxical leftward deviation (cross-over effect) was found in some patients, more frequently with short lines.

To assess the relationships between the different tests, a correlation matrix was calculated for paper-and-pencil measures. The great majority of correlation coefficients was positive and significant ($p < 0.0001$), and about one third of these coefficients had a value of 0.50 or more.

2.2.3. Patients with left hemisphere stroke

Neglect was clearly less frequent and less severe in the left hemisphere group [11]. As indicated in Table 3, paper-and-pencil tests revealed right neglect in 3.8% to 13.2% of patients, depending on the task. However, as far as 43.5% of patients demonstrated some degree of UN on at least one task. Personal neglect was just as frequent as extrapersonal neglect (9 and 13% with eyes open and eyes closed respectively), and was nearly as frequent as after right hemisphere stroke (16% and 13%). Anosognosia for motor and visual deficits was much less frequent than after right hemisphere stroke. Inter-tests correlations were low (<0.50).

2.3. Discussion

In healthy controls, there was a significant effect of age and/or education for the bells test, figure copying and writing, suggesting that these factors should be taken into account in the assessment of a patient suspect of UN. A significant effect of the acting hand was found only in line bisection. In this latter test, controls showed a mild but significant leftward deviation, a phenomenon known as “pseudo-neglect” [23,24,44]. This effect was larger with the left hand and with short lines, a result in accordance with a meta-analysis [44]. The effect of handedness is debated in the literature, and the lack of effect found in the present study should be taken with caution, due to the relatively low number of left-handed individuals ($n = 49$).

The battery was found sensitive to detect UN in patients with right hemisphere stroke. Indeed, more than 85% of patients showed UN on at least one test. An important finding was that an assessment across several different tests was more sensitive than any single test alone. This finding, in accordance with previous reports [41,52], suggests that a normal performance on one test alone is not sufficient to rule out the presence of UN. The two most sensitive tests were the bells test and the reading test, both including a strong visual component that has been suggested to exacerbate UN [9]. However, it should be emphasised that the number of left-sided omissions should not be considered as the sole marker of UN. The pattern of visual scanning used by the patient should be taken into consideration. Indeed, in the bells test, the most sensitive measure was the spatial location of the first circled bell. Contrary to controls, who used preferentially a left to right scanning strategy, a majority of patients started with a right-sided target. This supports the assumption that an early automatic orientation of attention toward the ipsilesional half of space is a major component of unilateral neglect [29,32,49]. Previous studies found that a rightward orientation bias was the only detectable residual impairment in patients who had apparently recovered from neglect [26,49]. In the line bisection tests, a length effect was found, in accordance with previous studies.
Table 3
Performance of patients (adapted from Azouvi et al., 2002 and Beis et al., 2004). LH = left hemisphere; RH = right hemisphere

<table>
<thead>
<tr>
<th>Test variables</th>
<th>Cut-off</th>
<th>LH stroke</th>
<th>RH stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>% pathologic</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td><strong>Bells test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omissions (total number)</td>
<td>&gt; 6</td>
<td>3.7 (2.5)</td>
<td>12.8</td>
</tr>
<tr>
<td>Omissions (left minus right)</td>
<td>&gt; 2</td>
<td>0.5 (2.1)</td>
<td>11.7</td>
</tr>
<tr>
<td>Starting point</td>
<td>&gt; 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Figure copying</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 0</td>
<td>0.4 (1.2)</td>
<td>10.4</td>
<td>1.2 (1.6)</td>
</tr>
<tr>
<td><strong>Clock drawing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 0</td>
<td>0.2 (0.6)</td>
<td>13.2</td>
<td>0.4 (0.6)</td>
</tr>
<tr>
<td><strong>Bisection (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-cm lines</td>
<td>&gt; 6.5</td>
<td>0.4 (19.7)</td>
<td>6.4</td>
</tr>
<tr>
<td>5-cm lines</td>
<td>&gt; 2.0</td>
<td>0.2 (2.9)</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Writing (left margin, cm)</strong></td>
<td>&gt; 7.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gaze and eye deviation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes open</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes closed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Personal neglect</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For hemiplegia</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For hemianopia</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

showing a linear increase in rightward displacement as a function of line length in most neglect patients [16, 39]. The cross-over effect for short lines has been reported in previous studies [39,48], although its mechanism remains a matter of debate. Nevertheless, these results suggest that bisection of short lines should not be recommended as a screening test for neglect.

Neglect was clearly less frequent and less severe in the left hemisphere group, in accordance with a large amount of previous studies, although this has been a matter of debate [1,7,22,31,41,52,54,66]. The present data showed that, depending on the criteria used, right UN was two to four times less frequent than left UN. Neglect was not only less frequent, it was only much less severe in the left hemisphere group as compared to patients suffering from a right hemisphere stroke.

An other difference between right and left UN was that paper-and-pencil tests were significantly correlated one with each other in the right hemisphere group, while there were only poor inter-tests correlations in the left hemisphere group. This finding suggests that right neglect is a somewhat elusive phenomenon, with less clinical consistency than left UN. In opposition with the findings obtained with paper-and-pencil tests, there was no such asymmetry with personal neglect that was not significantly more frequent after right hemisphere stroke. It should be acknowledged that the two groups were not systematically matched in terms of stroke size and severity, and that a few patients (n = 11), presumably with the most severe strokes, had to be excluded from the left hemisphere group due to comprehension deficits. Moreover, data on stroke localisation showed that the right hemisphere group tended to present more frequent antero-posterior and posterior strokes. Nevertheless, the two groups appeared to be quite similar in terms of associated motor impairments, suggesting that differences in stroke severity could not readily account for the dramatic differences in the frequency and severity of UN.

3. Behavioural assessment of UN: the Catherine Bergego Scale (CBS)

3.1. Materials and methods

3.1.1. Subjects

Several studies have been conducted successively with the CBS. Most of them were conducted in patients with subacute right hemisphere stroke in a rehabilitation setting. The first, preliminary study, included 18 patients, with the objective to assess inter-rater reliability. Further studies on psychometric properties of the scale have been conducted on two successive groups of patients with subacute-chronic right hemisphere stroke (n = 50 and n = 83 respectively) [4,5]. The CBS was also used in a subgroup of 69 patients in two participating centres of the previously mentioned validation study of the BEN [6].
Two of us (DP, PA) have more recently investigated behavioural aspects of right neglect in patients suffering from a left hemisphere stroke (unpublished data). Fifty-four patients suffering from a first-ever left hemisphere stroke were included. They were all right-handed. Time since stroke onset was 65.9 days ($SD = 40.5$). Stroke was ischaemic in 71.7% of cases.

3.1.2. Methods

The Catherine Bergego Scale (CBS) is based on a direct observation of the patient’s functioning in ten real-life situations, such as grooming, dressing, or wheelchair driving [4,5,13]. For each item, a four-point scale is used, ranging from 0 (no neglect) to 3 (severe neglect). A total score is then calculated (range: 0–30). Arbitrary cut-off points were drawn in the CBS, to distinguish different levels of impairment. Patients with a total score of 0 were considered as having no UN, a score ranging from 1 to 10 was considered as mild behavioural UN, a score 11–20 as a moderate UN and a score 21–30 as a severe UN. To assess patients’ awareness of neglect-related everyday difficulties, a parallel form of the CBS has been designed as a questionnaire, with the same ten items previously described. An anosognosia score can be computed by recording the difference between the observer’s and the patient’s scores.

3.1.3. Statistical analyses

Reliability was assessed by computing Cohen’s kappa coefficients on each of the ten items of the scale, and the correlation coefficient between the total scores given by two independent examiners [13]. Concurrent validity was assessed by comparison of behavioural assessment with the CBS to the results of conventional paper-and-pencil tests. Correlation coefficients between the CBS total score and conventional measures were computed. To further address the relationships between conventional and behavioural assessment, a stepwise multiple regression analysis was performed in the 69 patients from the validation study of the BEN. The total score on the CBS was used as dependent variable, and paper and pencil measures as explicative variables.

Internal consistency of the scale was established by measuring Spearman rank correlation between the scores on each individual question and the total score. The internal structure of the scale was assessed by two different methods on the data from 83 right hemisphere stroke patients from our department [5]. Firstly, a principal component analysis with varimax rotation was computed. In a second step, a Rasch analysis was computed (Bigsteps software) [47]. Rasch analysis is a method specifically designed for evaluating characteristics of rating scales with the expectation of unidimensionality [57,67]. Briefly, the Rasch model has been designed to assess the validity of ordinal scales and to permit the transformation of raw discontinuous scores into an equal interval measure.

3.2. Results

Inter-rater reliability was found satisfactory in the first group of patients ($n = 18$) who were scored simultaneously by two independent raters [13]. The kappa coefficients for the ten items of the scale ranged from 0.59 to 0.99, demonstrating a fair to high inter-rater reliability [13]. In addition, the total scores of the two examiners were strongly correlated one with each other (Spearman rank order correlation coefficient = 0.96, $p < 0.0001$) [13].

Spearman’s correlation coefficients between the scores on each individual question and the CBS total score were all significant, ranging between 0.58 to 0.88 [4]. A principal component analysis with varimax rotation ($n = 83$) extracted only one factor with an eigenvalue higher than 1, explaining 65.8% of total variance. All items of the CBS obtained a high loading on this factor (range: 0.77–0.84). Rasch analysis revealed that the ten items defined a common, single ability continuum with widespread measurement range and quite regular item distribution, and showed a satisfactory reliability [5].

In our three different studies [5,6,13], the three following items were found to be the most sensitive of the scale: neglect of left limbs, collisions while moving, and neglect in dressing. Behavioural assessment with the CBS was compared to the results of conventional paper-and-pencil tests. In our different studies previously mentioned, the total CBS score correlated significantly and relatively strongly with most paper-and-pencil tests. Bisection of short lines was the only test that did not correlate with behavioural neglect. The strongest correlations were obtained with the bells test with correlation coefficients always above 0.7 [4,5]. However, an important finding was that the CBS was constantly found to be more sensitive than conventional tests [4–6]. This point was addressed in the previously mentioned validation study of the BEN [6]. In this latter study, the highest incidence of UN found with any individual paper-and-pencil test was 50%, while 76% of patients demonstrated neglect on at least one item
of the CBS. Six patients performed within the normal range on the bells test and nevertheless showed a moderate to severe behavioural neglect on the CBS [6]. A stepwise multiple regression analysis found that four variables, from three paper-and-pencil tasks, significantly predicted the total CBS score (R square = 0.79, F(4.57) = 54.2, p < 0.0001): the total number of omissions and the starting point in the bells test, figure copying and clock drawing. These three tasks in combination revealed neglect in 148 patients (71.84%), and missed only 29 neglect patients (16.38%), most of whom had a mild neglect [6].

Patient’s self-assessment with the CBS was significantly lower than the examiner’s score (t(66) = −4.4, p < 0.0001), indicating some form of anosognosia of neglect-related difficulties in everyday life [6]. The difference was of 5 or more in 25 patients (37.3%). Anosognosia for behavioural neglect correlated significantly, although moderately, with anosognosia for motor and visual impairment (r = 0.29 and 0.37 respectively, p < 0.05). The anosognosia score correlated strongly with neglect severity, as assessed with the CBS (r = 0.82, p < 0.0001), or with paper and pencil tests (r ranging from 0.47 to 0.70, p < 0.0001), except for short-line bisection [6]. However, individual analysis revealed dissociations between anosognosia and neglect, some patients with moderately severe neglect obtaining anosognosia scores close to 0.

The study with the CBS in patients with left hemisphere stroke (unpublished data) revealed that 41 (77.3%) patients showed at least some neglect on one item of the scale (i.e. had a CBS score of 1 or more). However, only three (5.4%) had a CBS score higher than 10, corresponding to a clinically significant behavioural UN. This should be compared to the much higher rate of clinical significant neglect in patients with right hemisphere stroke (36%) [6]. The items from the CBS that obtained the highest scores (more severe neglect) were neglect of right limbs, neglect in dressing and mouth cleaning after eating, all corresponding to personal neglect. In opposition, items related to extrapersonal neglect, such as collisions while walking or wheelchair driving, obtained lower scores (Fig. 2). The CBS score was significantly correlated with the bells test (r = 0.41 with total omissions and 0.34 with right minus left omissions, both ps < 0.01), although the correlation coefficients were of lower magnitude than those observed in studies with right brain damaged patients (above 0.7). The CBS did not significantly correlate with line bisection. There were also significant correlations with functional disability, particularly with independence in basic activities of daily living (the Functional Independence Measure (FIM) [36] (r = −0.48, p < 0.01) and with posture and balance (Postural Assessment for Stroke Scale, PASS) [12] (r = −0.55, p < 0.001). Similarly to the findings obtained after right hemisphere stroke, the CBS score was significantly correlated with the presence of lesions in the left parietal cortex.

### 3.3. Discussion

These results suggest that the CBS is reliable and valid, and that the ten items define a homogeneous construct. The discrepancies between paper-and-pencil and behavioural assessments are very important to consider. We have repeatedly found that behavioural assessment was more sensitive to the presence of UN than any single paper-and-pencil test. This suggests that the diagnosis of UN should not be ruled out based on the performance on paper-and-pencil tests alone, without a careful examination of how the patient behaves in his real environment. In addition, it should also be mentioned that the CBS has been used in a rehabilitation trial in severe neglect patients, and was found sensitive to change, and useful to monitor patients’ improvement after rehabilitation [63].

The CBS is also useful to assess anosognosia of neglect in everyday life. Although anosognosia significantly correlated with UN, double dissociations were found between both disorders, in accordance with previous studies [19,28] Moreover, the data presented here suggest that anosognosia is not a unitary phenomenon [55] and that anosognosia for motor, visual or cognitive deficits can be dissociated from each other.

Findings from the study with left hemisphere stroke patients again suggested that right UN is much less severe than left UN. Clinically significant behavioural neglect (about 5% of patients) is much less frequent than after right hemisphere stroke. It seems that right UN is, like left UN, significantly associated with functional and balance impairments. These results may also raise the intriguing possibility of a qualitative difference between right and left neglect, with right neglect involving preferentially the personal rather than the extrapersonal space.

### 4. General discussion and conclusion

The studies summarised here illustrate the necessity to use a quantitative and validated test battery for...
assessment of UN. It is necessary to compare performance of patients with that of matched healthy controls. A significant effect of age and/or education was found for several tests in healthy controls, suggesting that these factors should be taken into account. Moreover, it is clear that clinical tasks for UN are of variable sensitivity. Tasks including a strong visual component were the most sensitive in our battery, and the automatic rightward orientation bias appeared to be the best indicator of unilateral neglect. In addition, several tests were more likely to uncover evidence of neglect than a single test. The BEN also addresses disorders such as personal neglect, anosognosia and extinction, that are not addressed in other widely used batteries.

Surprisingly, although UN in the extrapersonal space was more frequent and severe after right than left hemisphere stroke, personal neglect was of quite similar frequency in the two groups of patients.

An important finding, replicated across several studies with different groups of patients, was that behavioural assessment of neglect in daily life was more sensitive than any other single measure of neglect. As recently suggested [21], such behavioural measures should be included in any therapeutic trial of UN. The CBS is a reliable, valid and sensitive measure of behavioural neglect, that can easily be used in a rehabilitation setting. It also permits an assessment of anosognosia for neglect in everyday life, that can be dissoc-
ated from anosognosia for hemiplegia or hemianopia. Finally, it should be reminded that neglect is not an all-or-nothing phenomenon. Apparently recovered neglect patients may demonstrate signs of spatial bias when confronted to a novel situation [8]. Non specific factors, such as motivation, fatigue, emotional state, may also be of influence and should be taken into consideration in the assessment of neglect patients.

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References

A battery of tests for the quantitative assessment of unilateral neglect


