

# Neuropsychological outcome after a first symptomatic ischaemic stroke with ‘good recovery’

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**Background:** Neuropsychological impairment after stroke when no motor, sensory or language deficits are left remains understudied. The primary aim of this study was to assess neuropsychological outcome in a specific population of patients after a first symptomatic stroke without previous cognitive decline and with a good motor, linguistic, and functional recovery (i.e. ‘good outcome’). The secondary aims were to identify the profile of this potential impairment and relations between brain lesions and neuropsychological outcome.

**Methods:** Sixty consecutive patients were evaluated by a comprehensive neuropsychological assessment focusing specifically on executive and attentional functions but also on memory 109 days, on average, after the infarct. Patients were compared with 40 healthy controls matched for age and education.

**Results:** Patients showed lower performance in every cognitive domain compared with controls. Along with an important executive deficit, patients were also impaired on attention and memory. Patients were not more depressed than controls, although they were more apathetic. We also found a significant positive correlation between cognitive impairment and pre-existing white matter brain lesions assessed by MRI.

**Conclusions:** We report the first study examining the impact of a first stroke on cognition but also on psychiatric disorders in patients with good functional outcome. We found that patients considered as asymptomatic were, in fact, exhibiting a multidomain cognitive deficit that could impact return to life as before stroke.

## Introduction

It has been shown that, after stroke, on average, 30% of patients are cognitively impaired at 3 months, mainly on executive functions [1]. Relatives may also report personality changes or psychiatric disturbances such as depression [2]. The concept of ‘post-stroke cognitive impairment’ has emerged [3] but it is unclear whether it is an impairment of its own or a consequence of sensory-motor deficits, linguistic deficits, neglect or global functioning. These confounding factors have seldom been satisfactorily controlled.

The neuropsychological outcome of patients with ‘good recovery’, that is with no sensory-motor, language or neglect deficit is, in fact, poorly understood. These patients, who are considered as healed at 3 months, are supposed to resume their family, social, and professional life as before stroke. However, few studies have assessed their true cognitive status.

We decided to tackle this issue by conducting a prospective study evaluating the putative cognitive and psychiatric consequences of a first symptomatic stroke in the specific population of patients with ‘good recovery’ and without previous cognitive decline. The secondary aims were to identify the profile of this potential impairment and relations between brain lesions and neuropsychological outcome.

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## Methods

### Patients

We aimed at recruiting patients with good motor, linguistic, and functional recovery after a stroke. This recruitment was performed in two phases as follows: the first in our stroke unit during the acute phase and the second in the outpatient clinic between the third and fourth months.

#### *Acute phase*

We prospectively screened all consecutive patients between the ages of 18 and 80 years admitted to our stroke unit (Neurology Department, Purpan University Hospital, Toulouse, France) for a first symptomatic cerebral infarct between November 2007 and January 2009. Diagnosis of ischaemic stroke was based on the presence of both acute focal neurological deficit and brain ischaemic lesion on MRI diffusion-weighted imaging (DWI) performed within the first 2 days after the onset of symptoms. Patients with drug addiction, alcoholism, or general, neurologic, or severe psychiatric disease were excluded from the study at this point. Pre-stroke cognitive status was assessed using the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE). It is in our clinical experience to administer this questionnaire for each patient admitted in our unit. This is a brief questionnaire in 26 questions, which uses information provided by a close relative to assess cognitive functioning changes over the previous 10 years [4]. An IQCODE score above 3.6 points reflected a pre-existing cognitive decline and was an exclusion criterion [5].

National Institute of Health Stroke Score (NIHSS) at admission, cardiovascular risk factors, and drug intakes before stroke were also recorded.

Diffusion-weighted imaging and T2-weighted images (T2WI) images were performed for each patient amongst other clinical sequences not reported here. We focused our analysis on DWI showing recent ischaemic lesions and T2WI showing pre-existing brain lesions. The DWI was rated by a senior neuroradiologist blind for cognitive outcome based on the ASPECTS study [6]. We adapted this scale for MRI by adding four points for infratentorial infarct (midbrain, pons, bulb, cerebellum) for a total of 16 points. We also recorded stroke localization (cortical, subcortical, infratentorial, right, and left). T2WI white matter changes were rated using the Fazekas and Schmidt (F&S) rating scale [7]. This scale accounts separately for periventricular changes and deep white matter changes, scoring from 0 (no lesion) to 9 (extensive lesions).

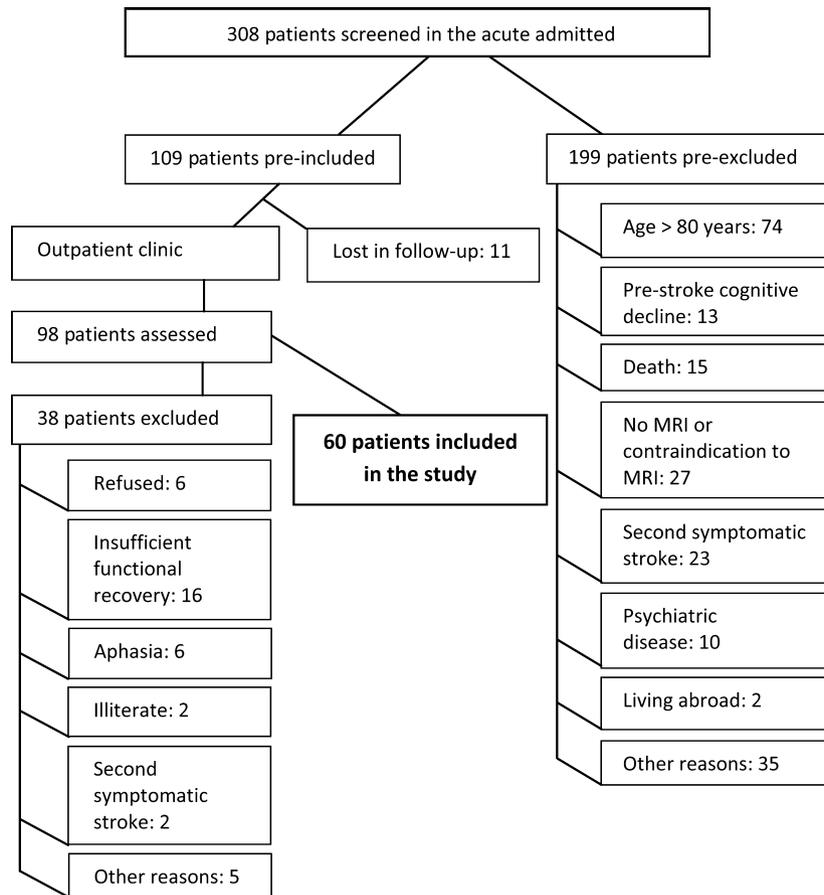
#### *Outpatient clinic phase*

Patients who met the inclusion criteria during the acute phase were assessed 109 days ( $\pm 20$  days) after the stroke. Level of education was evaluated using the GRECO questionnaire, a 4-point scale [8]. Amongst these patients, only the ones fulfilling the following inclusion and exclusion criteria were recruited. Inclusion criteria were as follows: fulfilling the acute phase criteria; very good sensori-motor; and functional recovery (NIHSS  $\leq 3$  [9] and modified Ranking scale (mRs)  $\leq 2$  [10]). Exclusion criteria were as follows: unable to speak, read, and write in French; the neuropsychological symptoms that can compromise a comprehensive neuropsychological examination such as aphasia assessed by subtests of the MT86 [11] (oral narrative speech, written understanding, object handling on verbal command, dictation, repetition, patients being excluded if any one of these tasks was failed); visual perception impairment assessed by a French standard confrontation naming test (D080 [11], performance less than  $-1.50$  SD); apraxia and neglect clinically assessed during the neurological examination; and any new cardiovascular event or general anesthesia since the acute phase.

Of the 308 patients screened in the acute phase, 109 were pre-recruited. Ninety-eight patients were assessed in the outpatient clinic after stroke. Sixty of them were recruited for the study (Fig. 1). According to DWI performed in the acute phase, 31 patients had a left, 24 had a right, and five had a bilateral infarct. Twenty-seven lesions were cortical, 20 subcortical, and 13 infratentorial. Mean ASPECT score was 2.19 (SD 1.44). The cumulated ASPECT score was 129 for the 60 patients including five points for the anterior cerebral arteries territories and 12 points for the posterior ones leaving 94 points for the medial cerebral arteries territories and 18 points for infratentorial infarcts. Mean F&S score was 3.22 (SD 2.39).

### Controls

A group of control subjects was recruited. Controls were spouses or relatives of the patients, or volunteers. Each control was clinically assessed by a general and neurological examination. History of stroke or abnormal clinical examination was a cause of non-inclusion in the study. Inclusion and exclusion criteria of patients group were applied to the control group. Controls were matched with the patients regarding age and level of education but not on cardiovascular risk factors. Control subjects did not undergo MRI. Forty healthy volunteers fulfilling inclusion and exclusion criteria were recruited.



**Figure 1** Flow chart of patients' recruitment.

### Neuropsychological assessment

Patients and controls underwent a comprehensive neuropsychological assessment encompassing 16 cognitive tests resulting in 30 raw scores. These scores were pooled in 13 cognitive functions (mental speed processing, motor speed processing, verbal working memory, visual working memory, inhibition, initiation, flexibility, categorization, continuous attention, errors of continuous attention, free recall, cued recall, recognition). Psychiatric disorders were assessed using three scales as follows: Spielberger's anxiety scale [12], Starkstein's apathy scale [13], and Beck's depression scale [14]. Global functioning was evaluated using cognitive complaint [15], quality of life [16], and anosognosia [17] scales (Table 1). This evaluation lasted approximately 2 h and was performed by a trained neuropsychologist during the outpatient clinic. Caregivers were asked to evaluate the patients' everyday abilities and behavioral disturbances using the Neuropsychiatric Inventory (NPI [18]) and Patient Competency Rating Scale (PCRS caregiver's form [17]). The NPI is a questionnaire administered to the patient's

caregiver and assessed behavioral disturbances in 12 domains. The PCRS is a 30-item self-report instrument which asks the subject to use a 5-point Likert scale to rate his or her degree of difficulty in a variety of tasks and functions in everyday life.

A clinical examination was performed during the outpatient clinic by a senior neurologist. NIHSS and mRS were used to assess neurological impairment and functional abilities. New cardiovascular events, modifications in medication, and drug intakes, specifically psychoactive drugs, were recorded in both groups. Details on neuropsychological tests can be found in Lezak [11].

### Vascular cognitive impairment no dementia

There is no consensus on vascular cognitive impairment no dementia (VCI-ND) criterion. Therefore, after clinical and neuropsychological evaluations, patients were considered as VCI-ND or as cognitively intact after a specific meeting attended by neurologists and neuropsychologists. VCI-ND was defined as impairment in at least one cognitive domain with a score below 2 standard deviation according to the control group in at least

**Table 1** Neuropsychological assessment: functions and tests

| Functions                    | Tests used   |
|------------------------------|--|
| Executive functions          |  |
| Mental speed processing      | Trail Making Test A, time [17]; Stroop labeling, time [17]; Stroop reading, time [17]; Digit symbol [11]   |
| Motor speed processing       | TEA battery (Divided attention), reaction time [33]; TEA battery (Flexibility), reaction time [33]; TEA battery (Go-no-go), reaction time [33]             |
| Verbal working memory        | WAIS-R digit span, forward [11]; WAIS-R digit span, backward [11]  |
| Visual working memory        | WMS-R spatial span, forward [11]; WMS-R spatial span, backward [11]  |
| Inhibition                   | Stroop interference, uncorrected errors [17]; Stroop test, subtraction score (I errors–L errors) [17]  |
| Initiation                   | Verbal fluency, fruit category [11]; Verbal fluency, letter (R) [11]   |
| Flexibility                  | Trail Making Test, subtraction score (B errors–A errors) [17]; TEA battery (Flexibility), errors [33]  |
| Categorization               | MCST, number of cards [17]   |
| Attention                    |  |
| Continuous attention         | TEA battery (Divided attention), correct responses [33]; TEA battery (Flexibility), correct responses [33]; TEA battery (Go-no-go), correct responses [33] |
| Errors, continuous attention | TEA battery (Divided attention), errors [33]; TEA battery (Flexibility), errors [33]; TEA battery (Go-no-go), errors [33]                                  |
| Memory                       |  |
| Free recall                  | RL/RI-16, sum of three free recall [11]; RL/RI-16, delayed free recall [11]; Rey memory, score [11]  |
| Cued recall                  | RL/RI-16, sum of three total recall [11]; RL/RI-16, delayed total recall [11]  |
| Recognition                  | RL/RI-16, recognition score [11]; DMS48, set 1 score [11]  |
| Psychiatric assessment       | Anxiety scale [12]; Apathy scale [13]; Depression scale [14]; NPI [18]   |
| Global functioning           | PCRS, Anosognosia score [17]; CCQ, score [15]; QoL, score [16]   |

TEA, Test of Attentional Evaluation; WMS, Wechsler Memory Scale; WAIS-R, Wechsler Adult Intelligence-Revised; MCST, Modified Card Sorting Test; RL/RI-16, Free recall/Cued Recall-16, a French equivalent of the Free and Cued Selective Recall test; NPI, Neuropsychiatric Inventory; PCRS, Patient Competency Rating Scale; CCQ, Cognitive Complaint Questionnaire; QoL, Quality of life.

two cognitive functions exploring this domain. VCI-ND was diagnosed in the absence of dementia according to the Diagnostic and Statistical Manual of Mental Disorders criteria, fourth edition.

### Statistical analyses

We first performed an intergroup comparison on demographic and clinical data using either a bilateral Student's *t*-test for independent samples or a chi-square test when appropriate.

To reduce the number of cognitive variables (30 raw scores), we pooled these scores in 13 cognitive functions (Table 1). A principal component analysis (PCA) was performed on the raw scores of each function. Using this method, we obtained a principal component representative of each of these 13 functions, allowing a legible representation of our results. MANOVA then *post hoc* analyses were carried out using Tukey's HSD (honestly significant difference) tests for samples with different sizes on every cognitive component. Correction for multiple comparisons is embedded in the Tukey's HSD analysis. These results were all confirmed using a MANOVA then Tukey's HSD tests on the 30 raw scores (Table S1). MANOVAS then Tukey's HSD tests were also used to compare the two groups on psychiatric disorders and global functioning on the basis of the raw scores. Size effects were estimated using Cohen's *d* on each

component of the PCA analysis. Following conventional criteria, an effect size of 0.20–0.30 was considered 'small', around 0.50 'medium', and above 0.80 'large'.

In the patients' group, we used Spearman correlations between the ASPECTS and F&S scores and neuropsychological data. Furthermore, three subgroups of patients were identified according to stroke location during the acute phase using the ASPECT score (cortical, subcortical, infratentorial), and their cognitive performance was compared using a single-factor ANOVA. STATISTICA® software 8th version (StatSoft, Tulsa, OK, USA) was used for all statistical analyses. A *P* level < 0.05 was considered as statistically significant.

### Ethics

Information about the study was given to each patient and control subject, and a consent form was signed at inclusion during the outpatient clinic. The study was approved by the local ethics committee (N° 31-1209).

### Results

#### Characteristics of patients and controls

The two groups were matched for age and education (Table 2). There were more men in the patients' group

**Table 2** Patients' and controls' demographic characteristics and cardiovascular risk factors

|   | <i>n</i> = 60<br>Patients'<br>means (SD) | <i>n</i> = 40<br>Controls'<br>means (SD) | <i>P</i> value |
|---|--|--|----------------|
| Sociodemographic factors                                |  |  |                |
| Age in years, mean (SD) <sup>a</sup>                    | 59.7 (14)                                | 57.2 (11.6)                              | NS             |
| Gender, % male <sup>b</sup>                             | 65                                       | 35                                       | < 0.01         |
| Level of education, mean (SD) <sup>a</sup>              | 2.8 (1.0)                                | 2.9 (1.1)                                | NS             |
| Psychoactive drugs intake, <i>n</i> person <sup>b</sup> | 4  | 7  | NS             |
| NIHSS on admission, mean (SD)                           | 2.6 (3.3)                                | –  | –              |
| NIHSS in the OPC visit, mean (SD)                       | 0.6 (1.3)                                | –  | –              |
| mRs score in the OPC visit, mean (SD)                   | 0.7 (0.8)                                | –  | –              |
| Cardiovascular risk factors ( <i>n</i> )                |  |  |                |
| Hypertension <sup>b</sup>                               | 62% (37)                                 | 17% (7)                                  | < 0.01         |
| Diabetes <sup>b</sup>                                   | 13% (8)                                  | 7% (3)                                   | NS             |
| Overweight <sup>b</sup>                                 | 20% (12)                                 | 17% (7)                                  | NS             |
| Nicotine addiction <sup>b</sup>                         | 40% (24)                                 | 12.5% (5)                                | < 0.01         |
| Hypercholesterolemia <sup>b</sup>                       | 52% (31)                                 | 32% (13)                                 | NS             |

NS, not significant; Level of Education was assessed using the GRECO questionnaire; NIHSS, National Institute of Health Stroke Score; mRs, modified Ranking scale; OPC, outpatient clinic. <sup>a</sup>*t*-test analysis; <sup>b</sup>Chi-square analysis.

(*n* = 39 vs. *n* = 21, *P* < 0.01). Intake of psychoactive drugs was the same in the two groups. History of hypertension and nicotine addiction was more frequent in patients than in controls.

### Neuropsychological assessment of patients and controls

MANOVA between the two groups on the PCA factorial coordinates showed significant statistical difference on the 13 functions assessed ( $F_{13} = 3.28$ ,  $P < 0.01$ ) (Table 3). This was confirmed on each of the 13 functions by Tukey's HSD tests. These analyses were confirmed by a MANOVA on the raw scores ( $F_{30} = 1.67$ ,  $P < 0.05$ ) (Table S1 for details), which yielded similar results. Additional analyses using Cohen's *d* indicated a 'large' size of effect for seven of the 13 cognitive functions [categorization ( $d = 1.20$ ), mental speed processing ( $d = 1.10$ ), initiation ( $d = 1.06$ ), free recall ( $d = 1.03$ ), verbal working memory ( $d = 0.96$ ), continuous attention ( $d = 0.93$ ), visual working memory ( $d = 0.92$ )]. A 'medium' size of effect was found for all other cognitive functions [motor speed processing ( $d = 0.75$ ); continuous attention, errors ( $d = 0.74$ ); flexibility ( $d = 0.70$ ); inhibition ( $d = 0.64$ ); recognition ( $d = 0.63$ ); cued recall ( $d = 0.57$ )]. Concerning psychiatric disorders, MANOVA showed significant difference on apathy ( $F_5 = 4.18$ ,  $P < 0.01$ ) and cognitive complaint ( $F_3 = 8.21$ ,  $P < 0.01$ ). No difference was found on depression, anxiety, anosognosia, and quality of life between the two groups (Table 4).

### Risk factor, stroke localization, and neuropsychological assessment

We assessed the effect of the presence of cardiovascular risk factors (hypertension, diabetes, nicotine addiction,

**Table 3** Comparisons (HSD Tukey test) between the two groups of cognitive function factorial coordinates<sup>a</sup> [Principal component analysis (PCA)]

|   | Patients' mean<br>factorial<br>coordinates (SD) | Controls' mean<br>factorial<br>coordinates (SD) | HSD<br>Tukey<br><i>P</i> value |
|---|---|---|--------------------------------|
| Executive functions (neuropsychological variables used in the PCA analysis) |   |   |                                |
| Mental speed processing [4]   | -0.39 (1.02)                                    | 0.58 (0.62)                                     | < 0.01                         |
| Motor speed processing [3]  | -0.28 (1.09)                                    | 0.42 (0.65)                                     | < 0.01                         |
| Verbal working memory [2]   | -0.34 (0.85)                                    | 0.52 (0.99)                                     | < 0.01                         |
| Visual working memory [2]   | -0.33 (1.01)                                    | 0.50 (0.75)                                     | < 0.01                         |
| Inhibition [3]  | -0.24 (1.21)                                    | 0.37 (0.30)                                     | < 0.02                         |
| Initiation [2]  | -0.37 (1.01)                                    | 0.56 (0.68)                                     | < 0.01                         |
| Flexibility [2]   | 0.27 (1.16)                                     | -0.39 (0.52)                                    | < 0.01                         |
| Categorization [1]  | 0.41 (1.05)                                     | -0.62 (0.46)                                    | < 0.01                         |
| Attention (neuropsychological variables used in the PCA analysis)           |   |   |                                |
| Continuous [3]  | -0.34 (1.13)                                    | 0.51 (0.41)                                     | < 0.01                         |
| Errors [3]  | 0.28 (1.13)                                     | -0.42 (0.55)                                    | < 0.01                         |
| Memory (neuropsychological variables used in PCA analysis)                  |   |   |                                |
| Free recall [3]   | -0.37 (1.02)                                    | 0.55 (0.67)                                     | < 0.01                         |
| Cued recall [2]   | -0.22 (1.18)                                    | 0.33 (0.50)                                     | < 0.03                         |
| Recognition [2]   | -0.24 (1.19)                                    | 0.36 (0.43)                                     | < 0.01                         |

Eigen value was always higher than one. <sup>a</sup>PCA coordinates are the values of the principal components, which are linear transformations of the original set of variables that explain at best the data variance.

**Table 4** Psychiatric assessment and global functioning

|                               | Patients' means (SD) | Controls' means (SD) | HSD Tukey P value |
|-------------------------------|----------------------|----------------------|-------------------|
| <b>Psychiatric assessment</b> |                      |                      |                   |
| NPI, severity total           | 2.65 (4.26)          | 1.92 (2.87)          | NS                |
| NPI, distress total           | 2.37 (5.34)          | 2.16 (3.85)          | NS                |
| Depression scale              | 4.02 (3.73)          | 3.28 (2.87)          | NS                |
| Anxiety scale                 | 40.10 (9.14)         | 39.98 (9.73)         | NS                |
| Apathy scale                  | 12.42 (5.06)         | 8.53 (3.55)          | <0.01             |
| <b>Global functioning</b>     |                      |                      |                   |
| CCQ                           | 2.78 (1.85)          | 1.28 (1.20)          | <0.01             |
| PCRS                          | 7.14 (33.93)         | 1.32 (11.43)         | NS                |
| QoL                           | 36.25 (7.08)         | 38.3 (5.52)          | NS                |

NS, not significant; NPI, Neuropsychiatric Inventory; CCQ, Cognitive Complaint Questionnaire; PCRS, Patient Competency Rating Scale; QoL, Quality of Life.

dyslipidemia, and obesity) on cognitive status. No significant effect was found between the subgroups of patients with and without these risk factors. There were also no significant differences between cortical, sub-cortical, and infratentorial subgroups or right or left infarct.

#### Correlations between MRI scores and cognitive performance

Although no significant difference was found between the localization of stroke and cognitive scores, we found a strong correlation between cognitive performances and F&S score. This score was significantly correlated with executive, attentional, and memory functions, whereas no cognitive function correlated with ASPECT scores (Table S2).

#### Vascular cognitive impairment no dementia

Forty percent of the patients ( $n = 24$ ) were diagnosed as having a VCI-ND. None of the patient fulfilled criteria of dementia. Amongst VCI-ND patients, only 66.6% ( $n = 16$ ) had a significant cognitive complaint (CCQ  $\geq 3$ ) and, amongst the non-VCI-ND patients ( $n = 36$ ), 33.3% ( $n = 12$ ) had a complaint.

#### Discussion

We report the first study examining the cognitive and psychiatric outcome of 60 consecutive patients with 'good recovery' 109 days after a first symptomatic stroke. Patients were relatively young and had no previous cognitive decline. We checked that these patients showed good sensori-motor, linguistic, and functional recovery. The decision was made to exclude patients with severe aphasia, apraxia, agnosia and neglect from

the study. These deficits, when they are remaining 3 months after the stroke, do not allow for a comprehensive neuropsychological evaluation. We found in the group of patients tested lower performance than in a control group on each of 13 cognitive functions assessed. Patients were also more apathetic than controls, but not more depressed. Moreover, we found a significant correlation between neuropsychological performance and pre-existing white matter lesions. This study demonstrates significant impairment in patients with 'good recovery' and shows that this clinical concept may be misleading.

In this study, patients showed 'good recovery' from a clinical point of view but were impaired on cognition and had psychiatric disorders. More specifically, patients compared with controls were impaired on each of the 13 functions belonging to the three cognitive domains tested (executive functions, attention, and memory). The size effect of this difference was considered as 'large' in 7/13 functions and 'medium' in the remaining six. This resulted in a multidomain cognitive impairment that was more severe than expected on the basis of clinical examination. Van Zandvoort *et al.* found similar results in a group of 16 patients for 6–27 months after a first lacunar stroke. In this study, motor outcome was not reported [19]. Controversial results are found in another study [20]. Whereas post-stroke executive function and attention deficits have been well documented in the previous studies, memory impairment after stroke is less well understood [21,22]. In our study, free recall was impaired. More unexpectedly, we found significant differences on cued recall and recognition tests, resulting of a mesial temporal pattern and thus suggesting a genuine memory deficit [23]. A recent study hypothesized that this specific memory impairment could be related to hippocampal diaschisis [24]. Thus, although the overall pattern of impairment found in our group appears to be largely dependent on frontal or sub-cortico-frontal systems, it could be that other impairment of other brain systems contributes to the syndrome.

The cognitive impairment shown cannot be related to depression as we found that patients were not more depressed than controls. This finding is not in line with what is commonly reported (30% of depression in post-stroke populations) [25]. However, these studies were carried out in the context of poor motor and functional outcome. On the other hand, we found that patients were more apathetic. In a recent study, Mayo *et al.* [26] have shown in a post-stroke population that even a minor level of apathy has an important and statistically significant impact on stroke outcome. In this study, patients' complaint remained minimal (2.78 on a

10-point scale vs. 1.28 for the control group, despite this difference being significant).

Forty percent of the patients ( $n = 24$ ) were diagnosed as having a vascular cognitive impairment – no dementia (VCI-ND). The complaint seems not to appear a sufficient indicator of cognitive impairment as only two-third of the VCI-ND is complaining about their cognition. It is then possible to argue that one-third of these patients should not be considered as having a VCI-ND but a subclinical neuropsychological impairment. A dedicated and systematic assessment has to be discussed during the post-stroke period to evaluate neuropsychological sequelae.

We found significant correlations between cognitive scores and pre-existing white matter lesions. This finding is well described in a population with risk factors [27] or with VCI-ND [28]. No correlation was found between cognition and acute ischaemic lesion location (ASPECT score). It is possible that VCI-ND is related to pre-existing white matter lesions that may have weakened a subcortical network compensated before stroke. This hypothesis could be combined with the concept of cognitive reserve [29]. It is, in any case, a hypothesis that could account for the pattern of impairment found in patients.

We performed this prospective study checking for major confounding factors such as the existence of previous stroke, previous cognitive decline, old age and stroke-related aphasia, apraxia, or neglect. Despite neuropsychological outcome after stroke having been widely studied, these factors have rarely been considered [21,30]. Patients and controls were not matched for cardiovascular risk factors, and no MRI scans were performed in the control group, which are limitations of our study. In particular, it is possible to argue that our results may have been influenced by cardiovascular risk factors being different in both groups, thus amplifying the cognitive deficit [31]. However, Popovic *et al.* [32] did consider this risk factor in their study and found cognitive impairment in the stroke group comparable to that reported here. Another unexpected result is the lack of significant difference between the two groups on quality of life. It is possible that our quality of life questionnaire was not appropriate to the post-stroke population (dedicated to Alzheimer's disease patients). Moreover, most of the patients recruited in our study were retired and may have had lower cognitive demand than still working patients.

Our study provides evidence that, despite a good recovery, post-stroke patients exhibit neuropsychological impairment. The patient's complaint was not a good reflect of this cognitive impairment. A systematic cognitive assessment has to be discussed in post-stroke patients, and everyday life repercussions need to be

better recognized. This study may change our clinical practice in post-stroke outpatient clinic. On the other hand, further studies are needed to better characterize the executive and memory deficits reported here and investigate their precise mechanisms so that new pharmacological and cognitive intervention can be designed.

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## Disclosure of conflict of interest

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Tukey's HSD tests on the 30 raw scores.

**Table S2.** Significant correlations between F&S and ASPECT scores and neuropsychological performances.

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