Cognitive aftermath of ischemic stroke
Gerritsen, Marleen Juliana Josephina

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Reasoning: impairment, recovery and impact on daily life

Reasoning can be considered a prerequisite to manage new problems in daily life. In this study reasoning after first-ever unilateral stroke was examined. For this purpose the Snijders Oomen Non-verbal Intelligence Test-R 5½–17 (SON) was administered in a community-based sample of 99 stroke patients at three and 15 months post stroke. With the same time interval 72 stroke free control subjects were examined. The results showed that compared to control subjects the stroke patients had decreased reasoning abilities that hardly improved over time. Side of lesion as such did not effect reasoning. There was however a negative influence of the presence of aphasia, neglect and memory impairment. Moreover, decreased speed of information processing was related to decreased reasoning performance. The activity level in daily life, as measured with the Frenchay Activity Index (FAI), was related to reasoning, more strongly than to suffering from a paretic arm or leg.


Submitted for publication.
Introduction

Stroke is a common disease that causes dramatic changes in a patient’s life. Reasoning can be considered a prerequisite to manage acquired disabilities, but only little research has focused on the course of reasoning after stroke and the impact of decreased reasoning abilities on the activity level in daily life. In this study a community-based patient group was studied, since especially those patients who go home after seemingly good recovery often experience surprisingly many difficulties in daily life. Moreover, this group has been relatively neglected in both neuropsychological research and care. Only recently the interest in cognitive functioning in the community-based stroke population has increased (Kase, Wolf, Kelly-Hayes, Kannel, Beiser, & D’Agostino, 1998; Patel, Coshall, Rudd, & Wolfe, 2003; Srikanth, Thrift, Saling, Anderson, Dewey, Macdonell, & Donnan, 2003). However, two of these studies used a cognitive screening test (Mini Mental State Examination) as the only measure of cognitive function (Kase et al., 1998; Patel et al., 2003).

Reasoning, fluid intelligence, concept formation, computation, problem solving, abstracting, generalising, ordering, organising, and planning are terms that are closely related, and can be clustered very broadly as 'thinking' (Lezak, 1995). The present study focuses on the capacity to solve new problems by thinking logically and the term reasoning will be used to describe this. The concept of reasoning is further outlined by the tests used to measure it.

According to Lezak (1995) a variety of tests can be used to measure reasoning capacities in adults, for example: the Raven Progressive Matrices (RPM), categorisation tasks, proverbs, the Wisconsin Card Sorting Test (WCST) and several WAIS-R subtests. Many of these tests rely heavily on language skills which is a fundamental problem in studying both left and right hemisphere stroke patients, considering that language problems occur in about a quarter of the stroke patients (Doesborgh, 2004). On the other hand, non-verbal tests, like the RPM, are visuospatial, which is an important disadvantage in examining right hemisphere stroke patients. There is evidence that the RPM is a useful tool to measure visual inattention and spatial problems, but not reasoning deficits after stroke (Blake, McKinney, Treece, Lee, & Lincoln, 2002). To overcome these problems the Snijders Oomen Non-Verbal Intelligence Test-R 5 ½ - 17 (SON-R 5 ½ - 17, Snijders, Tellegen, & Laros, 1989), was used in the present study. The SON is an internationally well known test for deaf children from 5 ½ to 17 years old, but can be used in adults as well (Gerritsen, Berg, & Deelman, 2001; Lezak, 1995). The test can be administered without verbal instructions or responses and contains subtests for abstract, concrete, and spatial reasoning.

The first main aim of the present study was to investigate both impairment and course of reasoning after stroke in a community-based patient group as well as the relations with other cognitive impairments. Several studies have reported impairments in test performances involving reasoning after stroke (Tatemichi et al.,
1994; Hom & Reitan, 1990; Leskelä et al, 1999; Glosser & Goodglass, 1990; Ballard, Rowan, Stephens, Kalaria, & Kenny, 2003). Much less is known about course of reasoning after stroke. Recently Ballard et al. (2003) showed that most patients in their study improved in cognitive functioning, including the reasoning test performance; i.e. the executive and abstract thinking subscales from the CAMCOG, between 3 and 15 months post stroke. However, these results were not corrected for possible retest effects by the use of a control group. Desmond and co-workers (1996) reported that in a group stroke patients who showed long-term overall cognitive improvement, this included the domains: memory, visuospatial functioning, and attention, but not language and abstract reasoning.

Moreover, much is unclear about the relation between reasoning and post-stroke cognitive disorders like memory disorders, aphasia and neglect. Both presence and severity of aphasia have been associated with a decline in non-verbal reasoning (Basso, Capitani, Luzzatti, & Spinnler, 1981; Kauhanen, et al., 2000). Glosser and Goodglass (1990), however, suggested that the impaired reasoning test performance, e.g. the Tower of Hanoi and the WCST, and three experimental executive tasks: the Non-verbal Continuous Performance Test, Graphic Pattern Generation Test, and Sequence Generating Test, in aphasic patients was independent of the linguistic deficits, but specific to lesions in the left frontal and prefrontal regions. In contrast, other studies found no specific role of the frontal regions in reasoning test performance in stroke patients, using the RPM and Wechsler Bellevue Performance subscales in one study, and the WCST in another (respectively: Basso et al., 1981; Leskelä, et al., 1999). With respect to neglect, right hemisphere patients with neglect have been found to perform worse than right hemisphere patient without neglect on the RPM. The right hemisphere patients without neglect were unimpaired compared to an orthopaedic control group (Soukup, Harrell, & Clark, 1994). In the present study the influence of aphasia, neglect and memory disorders on reasoning performance and long term improvement will be studied.

To our knowledge the role of speed of information processing in reasoning test performance has not been studied in stroke patients. In normal ageing, though, it is suggested that changes in reasoning capacities are, at least in part, mediated by an age-related decrease in speed of information processing (Schretlen et al., 2000; Verhaegen & Salthouse, 1997). In a previous study we showed that speed of information processing was slower in stroke patients than in an age-matched control group. Right hemisphere patients had slowed decision speed in simple visuomotor decision times as well as cognitive more complex decision times, whereas the left hemisphere group was only slowed in the cognitive complex tasks (Gerritsen, Berg, Deelman, Meyoom-de Jong, & Visser-Keizer, 2003).

The second main goal of the study was to investigate the association between reasoning abilities and activities of daily living, especially those activities that are complex and require decision making and organisational capacities. Activities that used to be fairly simple may have become rather complex after
stroke. A decrease in reasoning ability has been associated with lower levels of daily activities in some studies (Cockburn, Smith, & Wade, 1990; Wade, Legh-Smith, & Langton Hewer, 1985). Mercier and co-workers (2001) quantified the contribution of various factors to functional autonomy. They found motor deficits to explain most of the variance in functional autonomy followed by perceptual functioning and finally cognitive deficits. On the other hand, Sveen and colleagues (1999) showed no specific correlation between cognitive functioning and daily activities. In the present study the contribution of reasoning and motor deficits to complex daily activities will be examined.

In short, this study aimed to examine reasoning, using the SON-R 5½ -17, in a community-based patient group who suffered a clinically first-ever unilateral ischemic stroke. Impairment, relation to other cognitive disorders, course and impact on complex daily activities are studied.

**Methods**

**Participants**

Stroke patients were recruited from 100 general practitioners (GPs) in the northern part of the Netherlands, and from the stroke unit of the University Hospital Groningen. The GPs and the stroke unit presented 235 stroke patients. The stroke had to be a clinically first-ever, unilateral, ischemic stroke. According to the neurological or GPs’ reports, 188 patients met these criteria. Patients were excluded when they had other neurological or psychiatric diseases, or had a history of substance abuse (n= 13). Seventeen patients were unable to keep up the testing procedures for at least half an hour and nine patients died before testing took place. Aphasic patients were included in this study, unless they were unable to understand even the simplest test-instructions (n= 7). Finally, 43 patients did not want to participate in the interview and/or the neuropsychological testing procedure, so 99 patients entered into this study at about three months post stroke (T1).

Of this group 10 patients lived in a nursing home and two in a rehabilitation centre, the other patients lived at home and were at least partly independent. Fifty-six (56%) patients had a paretic arm, and 48 (49%) a paretic leg to at least some extent. One year after the first assessment (T2) 80 patients still participated in the study (3 had died, 3 were too ill, 2 had suffered a second stroke, and 11 did not want to co-operate any longer). In this group three patients lived in a nursing home, the other patients lived at least partly independently. Thirty-seven patients (46%) had a paretic arm, and 37 (46%) patients a paretic leg.

Control subjects (n= 72) were also recruited via the GPs. The controls were matched for age, gender, and education, and were clinically stroke free, had no neurological or psychiatric disorders, and no history of substance abuse. One year after the first assessment 64 control subjects were examined again (4 were too ill to participate any longer, 3 didn’t feel like it, and 1 moved abroad).
To our knowledge the SON-R 5 ½ -17 (SON) has not yet been used in adults in other studies, but according to Lezak (1995) the test can be used in patients with communication problems. In a pilot study we administered the SON in a group of 58 healthy elderly persons (52-83 years, mean= 70), and found it to be a feasible and valid instrument that showed good correlation with the RPM. The norms for the adolescents, however, appeared to be inapplicable because they underestimated the intelligence level in this normal healthy group; applying the normative data of the 17-year old to this group yielded an IQ of 80 on average (Gerritsen, et al., 2001). From the Committee of Documentation of Tests and Test research in The Netherlands, the SON-R 5 ½ -17 received highest marks on construction, material, normative data, reliability and validity. The RPM, for comparison, are considered to have ‘insufficient’ validity and norms, and the reliability is only ‘sufficient’ according to the same classification system (Evers, Van Vliet-Mulder, & Ter Laak, 1996).

The SON consists of seven subtests: two tests for concrete and two for abstract reasoning, two spatial tests and one perceptual test. All the SON-subtests consist of two or three parallel series, with an increasing level of difficulty within each series. The test procedure is adaptive; after two errors a series is discontinued and the score on this series determines the starting point in the following series. After each item, feedback is given whether the answer was right or wrong, without any further explanation, in order to give the subjects the possibility to adapt their strategy (Laros & Tellegen, 1991; Snijders, et al., 1989; Tellegen & Laros, 1993). The test was adapted for the target group (stroke patients) based on the results from our previous study with healthy elderly (Gerritsen et al., 2001). First, to minimize the strain on the patients three instead of seven subtests were administered:

- Categories (abstract reasoning): subjects have to choose two out of five line drawings that belong to three other drawings by discovering the underlying concept that binds these three drawings.
- Stories (concrete reasoning): subjects are asked to arrange a set of pictures into a story with a logical time sequence.
- Mosaics (visuospatial abilities): mosaic patterns have to be copied with red/white squares. There are six different kinds of squares, in the least difficult items only two types are used, in the most difficult items all six are used.

Second, all stimulus material in the Categories and Stories was presented vertically instead of horizontally to reduce the disadvantage of the patients with neglect as much as possible. Third, the time limits were prolonged with 50%. Moreover, basic criteria needed to complete the test, like sufficient vision and understanding of the test instructions, were assessed using simplified examples. Based on the performance on these simplified examples, three subjects appeared to lack the basic skills to complete all the subtests and were classified as ‘missing values’. The
separate subtest scores and sum of the subtests (SON-total) were used for statistical analyses; higher scores indicate better performance.

**Materials: aphasia and neglect assessment**

Aphasia was tested using two subtests from a Dutch aphasia test battery: Word comprehension and Sentence comprehension (SAN; Deelman, Koning-Haanstra, Liebrand, & van de Burg, 1981), and a 40-item object naming task (Butter, Berg, Deelman, & Maring, 1988). Cut-off scores were applied. Moreover aphasia, both expressive and receptive, was rated by one neuropsychologist, who was blind for the neuropsychological test data, as absent (score 0), mild (score 1), or severe (score 2). Combining these five scores led to a sum score with a minimum of zero and a maximum of seven points. Every patient with a sum score of two or higher was classified as aphasic. According to this classification 15 patients suffered from aphasia.

Neglect was tested using the Star-cancellation test (Wilson, Cockburn, & Halligan, 1987) and the Line bisection task (Schenkenberg, Bradford, & Ajax, 1980). The number of omissions on each tests, and a deviation of more than 10 percent from the true centres of the lines were used as cut-off criteria (Schenkenberg et al., 1980; Van Deusen, 1984; Soukup et al., 1994). The presence of neglect was also rated as absent (score 0), mild (score 1) or severe (score 2) by the neuropsychologist. Combining these four scores led to a sum score with a minimum of zero and a maximum of five points. Six patients, with a sum score of two or higher, had neglect.

**Materials: memory assessment**

To assess memory a paired-associate learning task (Couples Test) and the Rey Auditory Verbal Learning Test (AVLT) were used. The Couples Test contained a verbal (Names) and non-verbal (Faces) subtest. Subjects had to memorise 10 couples of male and female first names or male and female faces, in five successive trials. In each trial all stimuli, the couples, are presented, and immediate recall is measured by asking the subjects to match the females with the males (forced guessing). To reduce the chance for guessing five distracters, that is not previously presented female names or faces, were added when the recall was tested. The Dutch version of the AVLT is a test in which subjects have to learn 15 one-syllable words in five successive trials (Saan & Deelman, 1986). The sum score of the free recalls on the 5 trials was used. Memory impairment was defined as a total memory score that was lower than the 10th percentile in the control subjects (computed at T1). Fifteen patients (19%) had impaired memory according to this definition.

**Materials: speed of information processing**

Speed of information processing was measured using a reaction time apparatus that separately registered movement and decision times (Van Zomeren &
Deelman, 1976). In this study only the decision times, measured in milliseconds, were used. Because of intra-individual outliers in decision times, median scores were used. Visuomotor decision time was measured with a simple and an eight choice reaction time task. Cognitive decision time was assessed with two semantic categorisation tasks: one verbal (words) and one non-verbal (pictures). Previous analyses showed that visuomotor decision times and cognitive decision times actually measure two different aspects of speed of information processing (Gerritsen et al., 2003).

Materials: Frenchay Activity Index

The FAI is a frequently used, reliable tool to measure stroke outcome on the level of activities (Piercy, Carter, Mant, & Wade, 2000; Schuling, de Haan, Limburg, & Groenier, 1993; Wade, et al., 1985). The FAI has minimal overlap with the Barthel Index, a scale to measure less complex activities of daily living (Pedersen, Jørgensen, Nakayama, Raaschou, & Olsen, 1997). The FAI contains 15 items, each scored from 0-3, concerning activities at home as well as outside home (Holbrook, & Skillbeck, 1983). In this study we did not include the subscale 'domestic activities' because of the expected response bias due to traditional gender roles. Following a suggestion made by Schuling et al. (1993) we omitted the item 'gainful work'; considering the older age of a large part of the patient group this item lacked relevance (Schuling, et al. 1993; Sveen, et al., 1999). This means that our abridged version of the FAI contained nine items: shopping, social activities, go for a walk, occupying oneself with a hobby, travelling by car or public transport, making a trip, gardening, household / car maintenance and reading books. The scores range from 0 to 27, a higher score indicating a higher level of activity.

Procedure

Before participation informed consent was signed and the study was approved by the medical ethics comity of the University Hospital Groningen. In three sessions of two hours each, a structured interview and neuropsychological assessment took place. The first two sessions were at the participant’s home; the third at the University Hospital Groningen. Participants who were not able to come to the hospital were again visited at home. The first assessment, T1, took place in the subacute stage post stroke (mean= 116 days, sd= 32 days). One year later the measurements were repeated (stroke-T2: mean= 546 days, sd= 64). The control group was assessed with a one-year time interval as well.

Statistics

All tests were performed two-sided, and the alpha= .05 level was considered for significance. First, patients and control subjects were compared for age, gender and educational level with respectively Student’s t-test, Mann-Whitney-U and Chi-square tests. Second, the following psychometrics for the SON-R 5½ - 17 were
computed: Principal Component analyses, retest reliability and relation with demographic variables for both groups. Pearson’s correlation coefficient was computed for parametric, and Spearman’s rank correlation for the non-parametric data.

Third, the impact of stroke on reasoning was analysed using GLM-Repeated Measures with three measures: Stories, Categories and Mosaics. Only those participants who participated at both times of measurement were included in these analyses. Group (patients versus controls) was the between, and Time the within subjects factor. Moreover, the interaction Time x Group was analysed. The influence of lateralisation and stroke-related cognitive disorders were analysed, using four GLM-Repeated Measures analyses comparing left and right hemisphere patients, patients with and without impaired memory, with and without aphasia and with and without neglect. The respective Group effects and interactions Group x Time were computed. The predictive values of the stroke related cognitive disorders were analysed using stepwise regression analysis with the total-SON score as dependent variable and memory impairment, neglect and aphasia as dummy predictor variables.

Fourth, the role of speed of information processing in reasoning performance was analysed. The differences in speed of information processing between patients and control subjects were analysed, again using GLM-repeated measures. Then the correlation coefficients for speed of information processing and reasoning were computed for both T1 and T2. Moreover, GLM-univariate analysis with SON-total score at T1 as dependent variable was used to analyse the predictive values of the decision times for the patients and the control subjects. In the first step Group (patients versus controls) was entered as fixed factor, and Visuomotor Decision Times, and Cognitive Decision Times as covariates. In a second step the interactions between Group and the decision times were added to this model.

Fifth, and finally, the relation between reasoning and daily activities was examined. The daily activities of patients and control subjects were compared using GLM repeated measures. Then the correlations between the SON and FAI scores were computed for the patient group. GLM-univariate analysis with the FAI as dependent variable, paretic arm and leg as fixed factors and the SON-total score as covariate was used to analyse the role of these predictor variables.

Results

Subject characteristics

The subject characteristics at T1 and T2 are presented in table 1. There were no differences between the control group and the patients with respect to age, gender and educational level. Forty-six right hemisphere patients and 53 left hemisphere patients participated, they did not differ from each other in age (p= .99), educational level (p= .65) or gender (p= .68). At T2, 38 right hemisphere and
42 left hemisphere patients still participated, they did not differ in the demographic characteristics either.

Table 1:  Subject characteristic.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Age</th>
<th>Male</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M (sd)</td>
<td></td>
<td>M (sd)</td>
</tr>
<tr>
<td><strong>T1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>99</td>
<td>66.6 (11.9)</td>
<td>64%</td>
<td>3.9 (1.3)</td>
</tr>
<tr>
<td>Controls</td>
<td>72</td>
<td>66.0 (11.9)</td>
<td>54%</td>
<td>4.0 (1.4)</td>
</tr>
<tr>
<td>Group comparison</td>
<td>t = -0.30</td>
<td>χ² = 1.55</td>
<td>Z = -1.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p = .77</td>
<td></td>
<td>p = .21</td>
<td></td>
</tr>
<tr>
<td><strong>T2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>80</td>
<td>65.1 (11.2)</td>
<td>63%</td>
<td>3.9 (1.3)</td>
</tr>
<tr>
<td>Controls</td>
<td>64</td>
<td>67.8 (11.9)</td>
<td>56%</td>
<td>4.2 (1.38)</td>
</tr>
<tr>
<td>Group comparison</td>
<td>t = 1.0</td>
<td>χ² = 0.45</td>
<td>Z = -1.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p = .30</td>
<td></td>
<td>p = .45</td>
<td></td>
</tr>
</tbody>
</table>

Educational level was rated on a 7-point scale, ranging from 1, less than 6 years of education, to 7, university degree (Verhage, 1964).

**SON-R 5 ½-17: psychometric data**

The three SON subtests appeared to measure one concept in both the control group (Eigenvalue= 2.39, variance explained= 79.60%) and the patient group (Eigenvalue= 2.13, variance explained= 71.07%). The retest reliability of the adapted SON was high in both the control group (SON-total r= .93, Stories r= .85, Categories r= .82, Mosaics r= .90) and the patients (SON-total r= .90, Stories r= .81, Categories r= .76, Mosaics r= .88). The male controls performed better on the Mosaics than the female controls (F(1, 71)= 4.81, p= .03), but no other gender differences were found in the control or patient group. In both the control subjects and the patients the SON-total score was significantly negatively correlated with age and positively with the educational level (Age: control r= -.52, patient r= -.47; Educational level: control rho= .51, patient rho= .57), the same was true for all subtest scores.

**Reasoning after stroke**

The means, standard deviations and test statistics of the SON subtest scores are presented in table 2. The curves for course of reasoning are illustrated in figure1.
Table 2:  *SON test scores for patients and control subjects. Means, standard deviations and GLM-Repeated Measures test statistics for the reasoning subtests.*

<table>
<thead>
<tr>
<th></th>
<th>Patient (n = 71)</th>
<th>Control (n = 60)</th>
<th>Multivariate df : 3, 127</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Time</td>
<td>Time x Group</td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>F = 3.74, p = .01</td>
<td>F = 4.37, p &lt; .01</td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>F = 2.08, p = .11</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T1</th>
<th>T2</th>
<th>Univariate df : 1, 129</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Time</td>
<td>Time x Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F = 9.62, p &lt; .01</td>
<td>F = 8.26, p &lt; .01</td>
<td>F = 0.05, p = .82</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F = 10.33, p &lt; .01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Stories**
- mean: 6.92 (4.55) 7.72 (4.76) 9.45 (4.76) 10.13 (5.09)
- mean: 10.93 (5.90) 11.39 (6.30) 14.82 (6.70) 14.43 (7.15)
- mean: 13.48 (3.88) 14.25 (4.02) 15.52 (3.87) 15.53 (3.86)

**Categories**
- mean: 10.39 (5.90) 11.39 (6.30) 14.82 (6.70) 14.43 (7.15)
- mean: 6.22, p = .01
- mean: 1.33, p = .25

**Mosaics**
- mean: 16.22 (3.88) 14.25 (4.02) 15.52 (3.87) 15.53 (3.86)
- mean: 16.22, p = .01
- mean: 5.50, p = .02

Reasoning after stroke: patients versus controls

GLM-Repeated Measures revealed an overall significant main effect of Group, indicating that the stroke patients had impaired reasoning performance compared to the control subjects for all three subtests. Moreover, there was an overall main effect of Time, showing improvement in reasoning performance between T1 and T2, that was significant for the Stories and the Mosaics, but not the Categories. The interaction Time x Group failed to reach significance (p = .11), so overall the improved test performance was not different for both groups. At the univariate level, however, the interaction appeared to be significant for the Mosaics. As is shown in table 2 and figure 1, there is no change in performance in the control group, while the stroke patients slightly improved.

Figure 1: Course of the SON scores for the stroke patients (circles, continuous lines) and the control group (squares, discontinuous lines).
Reasoning after stroke: side of stroke

No significant main effect for side of stroke emerged (F(3, 67)= 0.48, p=.70). At the level of the subtests, none of the differences was significant either. Moreover, there was no difference in course of reasoning performance between the left and right hemisphere patients (Time x Side F(3, 67)= 0.20, p=.90).

Reasoning after stroke: memory impairment

Patients with impaired memory had overall worse reasoning scores than those without (F(3, 67)= 3.71, p=.02), this was significant for all three subtests (df(1,69): Stories F= 10.25, p< .01; Categories F= 4.90, p= .03; Mosaics F= 7.15, p< .01). However, there was no difference in course of reasoning performance between patients with and without impaired memory (Time x Group F(3,67)= 0.33, p=.80).

Reasoning after stroke: aphasia

The aphasic patients had worse reasoning scores than those without (Group F(3,67)= 5.08, p< .01), this effect was significant for all three subtests (df(1,69): Stories F= 10.04, p< .01; Categories F= 9.29, p< .01; Mosaics F= 13.62, p< .001). Aphasia did not effect course of reasoning performance though (Time x Group F(3,67)= 0.30, p=.83).

Reasoning after stroke: neglect

Finally, the neglect patients too showed worse reasoning performance than those without neglect (F(3, 67)= 2.78, p=.05), this was significant for the mosaics (F(3,69)= 6.69, p= .01), but not the Stories (F= 0.45, p=.50) or the Categories (F= 0.44, p=.51). There was no difference in course of reasoning performance (Time x Group F(3,67)= 0.12, p=.95).

When the cognitive disorders: memory impairment, aphasia, and neglect were entered into a stepwise linear regression analysis (see table 3) the performance on the Stories and Mosaics was significantly predicted by both aphasia and neglect. The performance on the Categories was predicted by aphasia only. Memory impairment had no independent relation with reasoning performance in these analyses.

Table 3: Linear stepwise regression analyses for the Stories, Categories and Mosaics. Only the significant factors are presented; memory impairment was not a significant predictor in any of the subtests.

<table>
<thead>
<tr>
<th>Significant predictors</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stories</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphasia</td>
<td>-.33</td>
<td>.16</td>
</tr>
<tr>
<td>Neglect</td>
<td>-.35</td>
<td></td>
</tr>
<tr>
<td><strong>Categories</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphasia</td>
<td>-.39</td>
<td>.15</td>
</tr>
<tr>
<td><strong>Mosaics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphasia</td>
<td>-.38</td>
<td>.22</td>
</tr>
<tr>
<td>Neglect</td>
<td>-.27</td>
<td></td>
</tr>
</tbody>
</table>
Reasoning and speed of information processing

GLM-Repeated Measures showed no overall main effect for group for the decision times (F(2,126)= 2.10, p = .13). At test level, however, the patients appeared to have slower visuomotor decision times (F(1,127)= 3.87, p = .05). The difference in cognitive decision times failed to reach significance (F(1,127)= 2.63, p = .11). The main effect Time was not significant (F(2,126)= 1.19, p = .31), nor was the interaction Time x Group (F(2,126)= 0.98, p = .38).

Correlations between the reasoning scores and the decision times are presented in Table 4. In both the patients and the control subjects the Cognitive Decision Times are significantly correlated with the reasoning scores. Most remarkable though, is the finding that the Visuomotor Decision Times are significantly related to the reasoning performance in the patient group, but not in the control subjects.

Table 4: Correlations between SON and decision times.

<table>
<thead>
<tr>
<th></th>
<th>Control VisuoDT</th>
<th>Control CognitiveDT</th>
<th>Patient VisuoDT</th>
<th>Patient CognitiveDT</th>
</tr>
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<td>-.49**</td>
<td>-.33**</td>
<td>-.53**</td>
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<td>-.30*</td>
<td>-.45**</td>
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<td>-.60**</td>
<td>-.40**</td>
<td>-.44**</td>
</tr>
</tbody>
</table>

Pearson’s correlations for reasoning and decision times; * significant at p < .05, **significant at p < .01.

For further analyses of the role of speed of information processing GLM-univariate analyses were performed. In the first step the SON-total score was predicted by Group (patients versus controls) as fixed factor, and Visuomotor Decision Times, and Cognitive Decision Times as covariates. The model explained 39% of the variance (R²= .39), with Group (F(1,122)= 8.02, p< .01) and Cognitive Decision Times (F(1,122)= 53.81, p< .001), but not Visuomotor Decision Times, as significant factors. Second, the interactions between Group and the decision times were added to the model. This second model explained about the same proportion of variance (R²= .41), but in this model Group was no longer a significant factor, instead Group x Visuomotor Decision Time was significant (F(1,120)= 4.61, p= .03). Cognitive Decision Time remained a significant factor (F(1,120)= 55.26, p<.001), but this effect was statistically the same for both groups (Categorisation Decision Time x Group: F(1,120)= 1.39, p=.24).

Reasoning and activities of daily life

At T1 the FAI-activity level of the patients (mean= 14, sd= 6.89) was significantly lower (F= 38.12, p< .001) than that of the control subjects (mean= 20, sd= 3.96). The same was true at T2 (patients: mean= 16, sd= 5.78; controls:
mean = 20, sd = 4.93; F = 14.74, p < .001). GLM-Repeated Measures analyses for the FAI revealed no significant effect of Time between T1 and T2 (F(1,126) = 1.02, p = .32), nor an interaction effect Time x Group (F(1,126) = 0.26, p = .61), indicating that the activity level did not change in time in either of the groups.

Correlations between SON scores and the FAI for the stroke patients are presented in table 5. Higher SON-scores were significantly related to higher FAI-scores at both times of measurement.

Table 5: Correlation coefficients between SON and FAI scores

<table>
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<tr>
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<th>T1 FAI</th>
<th>T2 FAI</th>
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<tr>
<td>SON-total</td>
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<td>.37**</td>
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<tr>
<td>Mosaics</td>
<td>.42**</td>
<td>.44**</td>
</tr>
</tbody>
</table>

* Significant at p < .05, ** significant at p < .01

In a GLM univariate model the SON-total score was entered as a covariate to predict the FAI-score. Moreover the physical impairments in terms of paretic arm and paretic leg were entered as fixed factors. The model explained 32% of the variance at T1 and 18% of the variance at T2, the data are presented in table 6. Table 6 shows that the SON is a significant predictor at both T1 and T2, the impairments in arms or legs only predicted the FAI score significantly at T1.

Table 6: Univariate GLM predicting the FAI-scores at T1 and T2

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th></th>
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<td>SON-tot</td>
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<td>.16</td>
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<td>Arm</td>
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<tr>
<td>Leg</td>
<td>4.56</td>
<td>.036</td>
<td>3.14</td>
<td>.04</td>
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</table>

Conclusions & discussion

The first aim of this study was to gain more insight in the level and course of reasoning abilities in a community based patient group with a clinically first ever, unilateral, ischemic stroke. The test used to assess reasoning in this study, the SON-R 5½-17 (Snijders, et al., 1989) had to our knowledge never been used before in stroke studies. Based on a prior pilot study with healthy elderly three out of the seven subtests were administered to measure abstract reasoning, concrete reasoning and visuospatial abilities. The three subtests appeared to measure one
general concept. The test showed high retest reliability in both patients and control subjects. Based on the present results and the results from an earlier study with healthy elderly we conclude that the adapted version of the SON-R 5 ½ -17 is a good and feasible instrument to measure reasoning abilities in both healthy elderly and stroke patients. Moreover, it was experienced as a more pleasant test that the Raven Progressive Matrices by the subjects (Gerritsen et al., 2001). However, in contrast to what was suggested by Lezak (1995), we found in our pilot study that the normative data from the test cannot be used in older adults (Gerritsen et al., 2001). In the appendix normative data derived from our present study and our earlier pilot are presented.

The present data clearly showed that in our community-based stroke sample reasoning performance was decreased compared to control subjects. Side of lesion as such did not have any effect on the test scores, even in the subtest that relied on visuoconstructive capacities no differences were found between left and right hemisphere patients. Neglect,aphasia, and memory impairment on the other hand, did have a negative effect on the reasoning scores. Like Soukup and co-workers (1994) we found that neglect patients had poorer scores on the visuospatial reasoning task than patients without neglect. No differences were found with respect to abstract and concrete reasoning, but considering the very small number of neglect patients in this study, it would be too speculative to conclude that non-spatial reasoning is not effected by neglect.

The finding that the presence of aphasia decreases non-verbal reasoning performance is in line with earlier studies as well (Basso et al., 1981; Kauhanen et al., 2000). It should be considered though, that non-verbal reasoning tests are non-verbal only in the sense that they do not require verbal instructions or responses, but one can never rule out that the most efficient reasoning strategies are indeed verbal, even in a visuospatial task like the Mosaics. Therefore it remains unclear whether decreased reasoning performance in aphasic patients is related to the aphasia per se, the stroke severity, or the lesion localisation as was suggested by Glosser and Goodglass (1990). Although memory impairment was related to worse reasoning, it was not an independent predictor when aphasia and neglect were entered in the analyses as well.

As was expected, based on the processing speed theory of normal aging provided by Salthouse (1996) that describes the relation between mental slowing and cognitive decline in more complex intellectual abilities, slower speed of information processing was related to worse reasoning in the present study. Moreover, this relation was not the same for the patients and the control subjects. No group differences were found for the relation between reasoning and cognitive decision times. More basic visuomotor decision times though, were related to reasoning performance in the patients, but not the control group. Even more, the data suggest that the stroke induced visuomotor slowing was a more important predictor of decreased reasoning capacities than the stroke per se.
Between the subacute and the chronic stage after stroke little recovery in reasoning took place. Although the reasoning scores improved in both the Stories and the Mosaics, only the Mosaics showed more improvement in the patients than in the control subjects, indicating some recovery of function and not merely a practice effect. While we found little evidence for recovery at group level, still it is possible that some patients recovered more than others. However, none of the stroke-related factors, side, aphasia, neglect, or memory impairment was significantly related to improvement of reasoning.

The second part of this study involved the impact of decreased reasoning abilities on complex daily activities as measured with an adapted version of the FAI. Poorer reasoning abilities were related to a lower level of activities in the stroke group at both times of measurement. Moreover, reasoning appeared to be a stronger predictor of the level of activity than the presence of a paretic arm or leg at both T1 and T2. This is in contrast with Mercier and colleagues (2001), who found motor impairment and not cognitive functioning to be the most important factor predicting functional outcome. Possibly this difference is due to methodological differences since we did not include balance that appeared to be a more important aspect of motor function than upper extremity paresis in their study. Moreover reasoning only made a small contribution to the cognitive factor they composed and the direct relation between reasoning and functional outcome was not assessed.

An important limitation of this study was that despite the reasonable number of patients that participated, the subgroups, especially the patients with aphasia and neglect, were very small. Moreover, the drop-out between T1 and T2 appeared to be selective with respect to the SON performance at the disadvantage of the patients who no longer participated at T2 (t = 3.63, p < .01). This was not true for the control subjects (t = 1.27, p = .21).

In sum, in this study we assessed a community-based patient group, which is in contrast with most other studies concerned with cognitive function after stroke that examined hospital-based groups or patients from a rehabilitation setting. We showed that this community-based patient group had impaired reasoning abilities that were stable until at least 15 months post-stroke. Reasoning appeared to be independent of the side of the lesion. Aphasia and neglect, on the other hand, were related to the reasoning capacities more strongly even than memory impairment. Moreover, basic slowing of visuomotor speed of information processing appeared to be related to decreased reasoning performance in the patient group, but not the control subjects. Impaired reasoning capacity appeared to contribute significantly to a lower level of daily activities as measured with the FAI. Even more, we showed that in this group reasoning was a more important predictor than a paretic arm or leg for the level of complex daily activities.
Most patients in the present study were only submitted to a hospital for a very short period of time, or not at all, and received little or no special treatment or care with respect to cognitive rehabilitation or education. More research is needed to establish the appropriate therapeutic interventions needed to optimise the stroke outcome in this patient group.
References


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Mercier, L., Audet, Th., Hébert, R.,


Pedersen, P.M., Jorgensen, H.S.,


### Appendix

*Normative data for 132 healthy persons*

<table>
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<td>5.4</td>
<td>1-23</td>
<td>46</td>
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</table>

**Total group**
Gender: male n = 54 (41%)
Age: mean = 65.8, sd = 11, range 37 – 89
Educational level: mean = 4.21, sd = 1.4, range 1-7

**37-50 years**
Gender: male n = 7 (41%)
Age: mean = 46.2, sd = 3.3, range 37 - 49
Educational level: mean = 4.9, sd = 1.1, range 3-7

**51-70 years**
Gender: male n = 30 (45%)
Age: mean = 62.87, sd = 5.0, range 51-70
Educational level: mean = 4.4, sd = 1.4, range 1-7

**71-90 years**
Gender: male n = 17 (35%)
Age: mean = 76.73, sd = 5.0, range 71-89
Educational level: mean = 3.7, sd = 1.3, range 2-6