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Assessment of calculation and number processing using the EC301 battery: Cross-cultural normative data and application to left- and right-brain damaged patients

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Abstract

To provide referential normative data on simple tasks dealing with number processing and calculation which could be used in clinical investigations, 551 normal volunteers aged between 18 and 69 years from France and Belgium ($n = 180$), Italy ($n = 212$) and Germany ($n = 159$), performed the 31 tasks which constitute the EC301 calculation and number processing battery. Differences between countries were significant for 16 tasks and a Gender × Education interaction was observed for some tasks, with men performing better than women among subjects with low education only. To present an overview of preserved and impaired calculation and number processing abilities in left-brain damaged (LBD) aphasic patients and right-brain damaged (RBD) nonaphasic patients, the 31 subtests of the EC301 battery were proposed to 80 patients with cerebrovascular accident, 56 left and 24 right, for most cases in the territory of the middle cerebral artery. LBD aphasic patients showed low performance on oral and alphabetical spoken verbal and written verbal counting, transcoding when a written code was involved, and mental or written calculation; but relatively good performance at finding the number of elements in small sets, comparing numbers written in the Arabic digital code and placing correctly numbers on an analogue number line. The lowest performances of RBD patients were observed for estimation tasks and for placing a number on a scale. Results and their implications for further research are discussed according to the present information processing and anatomofunctional models of calculation and number processing. (*JINS*, 2001, *7*, 840–859.)

Keywords: Calculation, Number processing, Brain damage, Aphasia, Normative data

INTRODUCTION

Group studies of brain-damaged patients show that mental calculation deficits are mainly observed in left-brain damaged (LBD) patients and that the performance of right-brain damaged (RBD) patients may not be significantly different from that of controls in simple arithmetical operations (Hécaen et al., 1961; Jackson & Warrington, 1986). Among LBD patients, language and calculation disorders can dissociate (Basso et al., 2000). However, RBD patients with retro-rolandic lesions can show deficits in some 'calculation' tasks with a strong 'spatial visualization' component (Dahmen et al., 1982), and in tasks involving magnitude comparison (Ardila & Rosselli,1994). Other cognitive dysfunctions, which are not necessarily related to laterality of brain lesion, affecting memory, attention, planning, etc., may also be associated to calculation deficits in brain-damaged patients (Carlomagno et al., 1999; Claros-Salinas, 1993; Fasotti, 1992; Parlato et al., 1992; Smith, 1980; Vilkki, 1988; Von Cramon et al., 1991). There is general agreement that there are many different types of 'calculation' tasks and that the results of comparisons between different groups of brain-damaged patients strongly depend on the particular cognitive demands of each task. To investigate further how many different cognitive components are involved in each task and whether these components are dependent or not on

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language, visuo-spatial skills, memory, etc., it is generally accepted that group studies should be supplemented by in-depth single-case investigations.

Most single-case investigations insist on dissociations of performance within the calculation and number processing area, which provide the main empirical background for the elaboration of information processing models (e.g., Macaruso et al., 1993; McCloskey & Caramazza, 1987; McCloskey et al., 1991a, 1991b). Patients with cerebral insult can show, for instance (1) specific difficulties to estimate and understand numbers, without any arithmetic calculation deficit (Guttmann, 1937), or on the contrary preserved estimation and understanding of numbers and correct strategies in problem-solving, despite a deficient knowledge of arithmetic facts (Warrington, 1982); (2) deficits in exact calculations but good performance in approximation of results (Dehaene & Cohen, 1991; see also Dehaene et al., 1999 for a study of normal subjects using functional brain imagery); (3) quite different performances according to the numerical system used, namely, Arabic, spoken verbal, written verbal (Gardner et al., 1975; Grafman et al., 1989; McNeil & Warrington, 1994; Noel & Seron, 1993) or the magnitude of the numbers to be processed (Cipolotti et al., 1991); (4) dissociation of performance on written calculations, with some arithmetical operations preserved (e.g., subtraction) and others impaired (Benson & Denckla, 1969; Lampl et al., 1994); (5) specific deficit (Ferro & Silveira Botelho, 1980), or on the contrary specific preservation of the recognition and understanding of arithmetical signs (Diesfeldt, 1993; Lucchelli & De Renzi, 1993).

Different functional architectures of number processing have been proposed to account for neuropsychological data. The model of McCloskey et al. (McCloskey, 1992; McCloskey et al., 1985) postulates a unique abstract/amodal representation of numbers, which is supposed to be involved in all numerical transcodings and calculation procedures. Observations of patients able to perform numerical transcoding 'automatically', i.e. without any reference or access to number comprehension (Cipolotti et al., 1995; Cohen et al., 1994; Deloche & Seron, 1987), and reports of patients showing dissociations in the access to number facts according to mode of presentation (McNeil & Warrington, 1994), seem difficult to reconcile with a unique numerical representation model. The "triple code" model (Dehaene, 1992), postulates three different interconnected representations of numbers, analogical (e.g., on a scale), verbal (spoken and written words) and visual–Arabic. The analogical representation system is supposed to be related to preverbal skills, (i.e., relatively language-independent) and allows estimation, approximation, magnitude comparison, and *subitizing* (i.e., immediate visual perception of the number of elements in small sets; Folk et al., 1988). Tables and arithmetic facts, counting, and input/output processes dealing with transcodings of spoken and alphabetically written numbers depend on the verbal representation of numbers. Written calculations, parity, and input/output processes dealing with Arabic numbers depend on the visual Arabic representation of numbers. This model accounts for 'automatic' number transcodings, possible preservation of processes involving Arabic numbers in aphasic patients, and dissociations between comprehension/estimation of numbers and calculation procedures or number facts.

Given the above findings and models, a number processing and calculation battery for neuropsychological testing should include (1) numbers of different magnitude presented in the three numerical systems, Arabic, spoken verbal, and written verbal; (2) exact calculation tasks as opposed to estimation, approximation and magnitude comparison tasks; (3) number production tasks as opposed to number comprehension tasks; (4) procedural knowledge tasks as opposed to tasks involving knowledge of arithmetical facts; (5) tasks exploring the spatial arrangement of numbers, involving subitizing, or production and recognition of the arithmetic signs.

Moreover, to decide whether an observed low number- or mathematics-related performance in a brain-damaged patient of a given educational level, sex, age, and cultural origin, should be considered as an indicator of a pathological state due to the anatomical lesion or, on the contrary, as merely the usual pre-morbid performance of the patient, it is necessary to have normative data for each of the tasks proposed. This problem is particularly acute if the patient has a low educational level. In the area of calculation in normal subjects, gender effects have often been reported (Hyde et al., 1990). Possible age effects on simple arithmetics in normal adults indicate controversial results (Deloche et al., 1994, 1999b; Geary & Lin, 1998; Jackson & Warrington, 1986; Villardita et al., 1985). Cross-cultural comparisons of calculation and mathematical skills show important culture and country effects. A well-known finding is that East-Asian children (e.g., from China, Japan, and Korea) consistently outperform their American and European counterparts on mathematical tests (Geary et al., 1996; Miura et al., 1994; Towse and Saxton, 1997). One among many proposals to explain this observation is the role of linguistic factors in the acquisition of numerical skills. Number-naming systems are much more regular in East-Asian languages than in English or French (e.g., the English 'eleven' and 'twenty' are 'ten-one' and 'two-ten' in Japanese, respectively). From this perspective, the direct comparison on the same battery of normal adults from Italy (relatively simple numerical system), France (with some irregularities in three decade names, i.e., 70, 80, and 90 are "sixty ten," "four twenty," and "four twenty ten," respectively) and Germany may clarify the issue of the possible effect of the complexity of the verbal numerical system that may still be present in low-educated adults.

In the past, the assessment of calculation and number processing has received relatively little attention and therefore arithmetical tasks are only a very minor part of standardized batteries (e.g., there are only 14 items in the widely used WAIS–R; Wechsler, 1981). Multi-task batteries covering a large number of numerical abilities have been developed for the purpose of in-depth single case analyses (e.g., Cipolotti et al., 1991; Cuetos & Miera, 1998; Dehaene & Cohen, 1998) or for group studies (e.g., Ardila & Rosselli, 1994; Collignon et al., 1977) but without clear reference to normative data. Other studies evaluated patients' performance with respect to controls, but generally on a small number of participants (e.g., 15 normal controls in the battery of McCloskey et al., 1991a) or on a very limited number of 'calculation' components (e.g., Jackson & Warrington, 1986; Takayama et al., 1994).

Thus, given the variety of numerical skills and dissociations following brain injury, and the effect of individual factors on the performance of normal subjects, there is a need for comprehensive normative data available for clinical purposes.

The EC301 battery is composed of 31 subtests (Table 1), exploring the following 13 areas, which can be further justified from a neuropsychological point of view (see Appendix 1 for detailed items of each subtest).

Number Sequences

The production of the conventional sequence of number words is a prototypical example of an automatized verbal process in normal adults (Logie & Baddeley, 1987) and plays an essential role in the acquisition of arithmetical skills (Fuson et al., 1982). For brain-damaged patients, counting by ones may be a backup procedure used for bypassing their difficulties when asked to count with a different step (Seron & Deloche, 1987) or when failing to directly address number facts (Warrington, 1982). Counting backwards is supposed to be under the control of the working memory system (Nairne & Healy, 1983), and may indicate deficits in executive functions (Parlato et al., 1992).

Enumeration of Dots

Counting the number of elements in arrays is one of the most basic and natural numerical activities. The subitizing phenomenon allows for the direct evaluation of the number of elements at one glance, but it holds only for small sets of about four or five elements (Dehaene & Cohen, 1994). In such visuospatial and linguistic tasks, brain-damaged patients may go wrong for a variety of reasons (Seron et al., 1992). Visual hemineglect would cause the omission of dots. Memory impairments would disrupt the partition between the already-counted and the to-be-counted dots. Aphasic

Table 1. The Calculation and Number Processing Battery: List of subtests

Subtest	Max. score
C1: Spoken verbal counting	8
C2: Arabic digit counting	2
C3: Written verbal counting	4
C4: Enumeration of Dots (ED). Small sets (6,4,5) on Dominoes	6
C5: ED. Small sets (4,6,5) on random spatial arrangements	6
C6. ED. Medium size sets (11, 8, 10) on segmentable arrangements	6
C7. ED. Medium size sets (10,8,11) on random arrangements	6
C8. ED. Medium size sets (9,7,12) on linear arrangements	6
C9. Numerical transcoding (NT): Oral repetition of numbers	12
C10. NT: from Arabic digit to written verbal numbers	12
C11. NT: Reading aloud numbers in Arabic digit forms	12
C12. NT: Writing to dictation written verbal numbers	12
C13. NT: Reading aloud numbers in written verbal forms	12
C14. NT: Writing to dictation Arabic digit numbers	12
C15. NT: From written verbal to Arabic digit numbers	12
C16. Arithmetical Signs (=,×,−,+). Naming	8
C17. Arithmetical Signs (=,×,−,+). Writing from dictation	8
C18. Magnitude Comparison of numbers (Arabic digit code)	16
C19. Magnitude Comparison of numbers (Written verbal code)	16
C20. Mental calculation on spoken verbal numbers	16
C21. Mental calculation on Arabic digit numbers	16
C22. Approximation of the result of an operation	16
C23. Place of a number on an analogic scale. Written presentation	10
C24. Place of a number on an analogic scale. Oral presentation	10
C25. Place multidigit numbers to perform an operation	8
C26. Written calculation. Additions	4
C27. Written calculation. Subtractions	4
C28. Written calculation. Multiplications.	7
C29. Magnitude approximations of pictured stimuli	12
C30. Contextual magnitude judgments	10
C31. Precise numerical knowledge	12

patients may produce verbal paraphasias that disturb their counting.

Numerical Transcodings

From a general information processing point of view, transcoding refers to the process associating a given representation in some source code (e.g., the Arabic number “205”) to the corresponding representation in some other notational system (e.g., the written verbal number “two hundred and five”). Reading aloud (i.e., transcoding written forms into spoken forms) is a common example of such cognitive verbal abilities. In the area of numbers, transcoding errors have received particular attention during the past 20 years (Dehaene, 1992; Deloche & Seron, 1987; Kessler & Kalbe, 1996; McCloskey et al., 1985).

Arithmetic Signs

These subtests were included because acalculic patients have been reported with errors in recognizing operation signs (Diesfeldt, 1993; Ferro & Silveira Botelho, 1980).

Magnitude Comparisons

The task aimed at evaluating number comprehension processes in two different numerical systems, Arabic and verbal written, since these processes may be disrupted independently of calculation and number processing (Deloche et al., 1995).

Mental Calculations

These subtests aimed at evaluating number facts in order to disentangle calculation errors due to handling erroneous procedures from those originating from impaired knowledge of arithmetical facts as indicated by performance dissociations (e.g., Cohen & Dehaene, 1994b; Hittmair-Delazer et al., 1995; McCloskey et al., 1991a; Warrington, 1982).

Calculation Approximations

Performing numerical approximations is a daily task that may be impaired or preserved independently of other numerical and calculation activities (Barbizet et al., 1967; Dehaene & Cohen, 1991). Subjects have to estimate approximately the result and not actually perform the operation.

Placing Numbers on an Analogue Number Line

The task evaluated number comprehension using an analogue magnitude representation system similar to the one proposed by Dehaene and Cohen (1995). In order to analyze possible dissociations as the ones already reported (Grafman et al., 1989; McCloskey et al., 1985), numbers were presented in two ways: Arabic digits and spoken verbal forms.

Writing Down an Operation

Some acalculic patients show difficulties in the conventional spatial arrangement of numbers in arithmetical operations (Caramazza & McCloskey, 1987; Hécaen et al.,1961). This task specifically tests the ability to spatially organize two Arabic numerals in order to perform the calculations.

Written Calculation

The operations were selected in order to investigate how the subjects mastered the sequence of procedural actions involved in written calculations, namely the conventional spatial processing of the operations on pairs of digits (as intermediary operations and results to be written down), and particular problems like borrowing or carrying. Given the above-mentioned dissociations between calculation procedures and number facts, the items of these subtests were constructed in such a way that the number facts involved in the operations should be as easy as possible according to the norms provided by Campbell and Graham (1985).

Perceptive Estimation of Quantities

This task explores the ability of subjects to perform numerical estimations of visual patterns. Subjects with lesions of the right hemisphere were reported to perform significantly lower than controls and left brain-damaged patients on such tasks (Warrington & James, 1967).

Contextual Magnitude Judgments

The task evaluates the ability to give a semantic interpretation of numbers in contextual situations where their relative semantic magnitudes do not necessarily follow their numerical values (Banks et al., 1976).

Precise Numerical Knowledge

Accessing numerical information from semantic memory outside the context of arithmetical processing may be disrupted independently of number facts stored for performing operations (Grafman et al., 1989). Subjects are presented with questions on their knowledge of specific facts (e.g., number of minutes in 1 hr).

The French version of the battery is presented in a previous paper (Deloche et al., 1994), with a report of the effects of age, gender, and education in a sample of 180 normal subjects. For an application of the Italian version in vascular brain-damaged patients see Basso et al. (2000). The present paper presents additional normative results from two other European countries (Germany and Italy) and a

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neuropsychological application of the French version in patients with left- or right-hemisphere cerebrovascular accident, either ischemic or hemorrhagic, mainly affecting the territory of the middle cerebral artery. The present study does not include true illiterates but does include a sample of normal Italian subjects with very low education (3 or 4 years of formal schooling), which allowed to look for a differential effect of education across the 31 subtests of the EC301 battery.

The aims of this study are (1) to establish and provide referential normative data; the presentation adopted allows not only the use of the battery as a whole, which is time-consuming (between 30 min and 1 hr) but also the selection of individual task(s) for testing a particular neuropsychological and cognitive hypothesis; (2) to compare the patterns of preserved/impaired performance in RBD and LBD patients, on a variety of tasks involving calculation and number processing, and more specifically to clarify which tasks are related to aphasia, right-brain damage or both. Results and their implications for further research will be discussed according to the present information processing and anatomofunctional models of calculation and number processing.

METHODS

Research Participants

Normals

Participants were 551 volunteers without known history of neurological, psychiatric pathology or developmental dyscalculia, divided into 265 men and 286 women, aged between 18 and 69 years. Three languages were represented: French (from France and Belgium; $n = 180$), Italian (from Italy; $n = 212$) and German (from Germany; $n = 159$). Forty subjects, all from Italy, had a *very low* educational level (3 or 4 years of schooling), and 171, 171 and 169 subjects a *low* (5 to 8 years of schooling), *medium* (9 to 12 years) and *high* (more than 12 years) educational level respectively (Table 2a). Subjects were native speakers. The battery was administered by clinical psychologists, speech therapists or linguists working in neuropsychological rehabilitation centers. In order to avoid a possible geographical bias in the sample, French-speaking subjects were recruited from six different regions, including one in Wallonia (Belgium). For German controls, data were predominantly collected in the area of Munich (South Germany), meaning that subjects originated from all parts of the country, except the eastern parts. Many of the younger controls were working in the hospital of München-Bogenhausen, whereas the oldest were chiefly visitors of a meeting center for elderly people run by the City of Munich. Italian controls were recruited in Milano, Padova and Rome, which covers almost all of the Italian regions except the South and the islands.

Table 2a. Description of the sample

Variable	France	Italy		Germany
N	180	40	172	159
Gender				
males	90	20	85	70
females	90	20	87	89
Age				
M (*SD*)	47.1 (15.6)	58.0 (7.7)	47.8 (15.2)	44.8 (15.2)
18–39	60	0	61	61
40–59	60	19	78	60
60–69	60	21	73	38
Education				
<5 yrs	0	40	0	0
5–8 yrs	60	0	59	52
9–12 yrs	60	0	58	53
>12 yrs	60	0	55	54

Patients with stroke

Eighty right-handed French patients were recruited from different neurological departments of hospitals in the area of Paris. Their lesions were localized by CT scan and/or MRI. All patients presented cerebrovascular accident, ischemic or hemorrhagic, for most cases in the territory of the middle cerebral artery of the right hemisphere ($n = 24$) or the left hemisphere ($n = 56$). As Table 2b shows, the age of the patients and the delay since the accident were not significantly different between the two groups (i.e., right- and left-CVA). Neuropsychological information was provided by the local clinical staff. Almost all patients of the left-CVA group were aphasics (with 2 exceptions); aphasia was absent in the right-CVA group. The calculation battery was administered by two speech therapists who were not in charge of the patients.

Table 2b. Description of the sample of 80 patients with CVA

Variable	Right hemisphere CVA	Left hemisphere CVA
N	24	56
Age: yrs		
M (*SD*)	51.6 (10.6)	50.6 (13.4)
Range	29–69	22–75
Delay: Months		
M (*SD*)	10.2 (24.1)	10.6 (21.9)
Range	1–120	1–156
Gender		
Women/men	12/12	21/35
Education*		
1/2/3	12/5/7	15/18/23
Aphasia		
% yes	0%	95%
Hemiplegia		
% yes	58%	70%

Note. *1 = 5–8 years; 2 = 9–12 years; 3 = >12 years.

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Procedure

Number sequences

The three subtests provide the examiner with the opportunity of assessing the production of all the basic lexical primitives of the three numerical systems: the units, teens and decades of the verbal system in their spoken (C1) or written (C3) forms, and the 10 Arabic digits (C2). For each item, the instructions indicated to subjects the particular numerical system for producing the sequence, the direction of the series (forward or backward), its starting point and the increment. Correct responses were scored 2 points per item. When subjects had difficulties in responding, they were given a second trial. The examiner repeated the instructions and provided not only the starting point of the sequence but also the next element. Correct responses following the second trial received only 1 point per item. In C1, filled or empty pauses and simple repetitions that appeared like pauses were not considered errors. In C2, subjects had to work silently. In C3, literal paragraphias that did not alter the phonological reading of lexical primitives were not considered errors.

Enumeration of dots

Subjects were presented with patterns of dots printed on a sheet of paper and had to indicate the number of dots on each sheet in Arabic digit form. For each item, correct responses produced in Arabic digits were scored 2 points, but only 1 point when delivered in another numerical system (e.g., spoken verbal numbers). The different subtests aimed at evaluating the possible effects of factors such as size of the sets to be counted, type of the spatial distribution of the elements, and enumeration constraints. For Subtests C6, C7 and C8, subjects were asked to point successively to the dots one after the other, while counting them aloud.

Numerical transcodings

Given the three usual notational systems for numbers, there are six possible transcodings between one system and the other, in addition to repetition, there were thus seven subtests. Due to the time constraint of such a clinical examination, it was not possible to present subjects with items illustrating all the linguistic structures of the numerical systems and their transcoding peculiarities. Therefore the number of items in each subtest was limited to six. Each item exemplified a different syntactical frame, and these six frames, were common to the seven subtests. Moreover, in some subtests, the six items were exactly the same. In order to avoid learning effects the seven subtests were not administered in sequence, but they were distributed at different places in the battery. For each subtest, instructions carefully explained the particular task and an example was given before starting the test. When stimuli were presented as spoken verbal numerals, the examiner could repeat once the entire number on request of the subject, but correct responses following stimulus repetition received 1 point instead of 2 points. The additions, omissions, substitutions or displacements of lexical primitives (digits or number words) were scored as errors, but phonetic or phonemic transformations in oral production, and dysorthographic written verbal responses were not considered errors when the target elements were unambiguously recognizable.

Arithmetic signs

There were two subtests: naming four arithmetic signs (=, ×, −, +), and writing them from dictation. The division sign was not used because a pilot study showed that too many controls were at fault with it.

Magnitude comparisons

Subjects were asked to indicate which number in a pair was the largest. Half of the pairs presented the largest item first. Only one item (pair of two numbers) was shown at a time. Subjects were asked to carefully look at the two numbers before making their choice of the largest. Correct responses received 2 points.

Mental calculations

The same operations and items were presented in the two subtests allowing a direct comparison of results. However, the two modalities, spoken numbers and Arabic numerals, were not presented in direct succession, in order to avoid possible learning effects from the first subtest onto the second one.

Calculation approximations

Each problem was presented with the two operands on the same horizontal line. The examiner pointed to the arithmetical sign, saying "this is an operation," then to the two numbers, "on these two numbers," then to the four-number array "and these are numbers; just show me the one closest to the result of the operation." Subjects were instructed not to try to compute the exact result, because they would not have the time since the problem was shown for 10 s only. The four-number multiple choice array was constructed according to the following criteria: the correct response is very near to the correct solution of the operation (i.e., the magnitude difference is always less than ± 10%; one distractor is about the double of the correct solution; one distractor is about the half of the correct solution; one distractor is an approximation of the result of the "reverse" operation (+ *vs.* −; × *vs.* ÷) performed on the same numbers. Correct responses received 2 points per item.

Placing numbers on an analogue number line

The subject had to point to the place of a number on a scale presented vertically with zero and 100 as marked ending points (at bottom and top, respectively) and four possible choices indicated by ticks. Each presentation was com-

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posed of five items which were different but comparable in magnitude since they differed only by one unit. In both presentations the five items were distributed in order to cover different regions of the number line. In each case, there was a vertical number line intersected by four small horizontal segments, one corresponding to the right place, and three others acting as distractors. Attention was paid so that the distractor marks should not be spatially too close to the correct mark. Before looking at (Subtest 23) or hearing (Subtest 24) the number to be positioned, subjects were shown the numerical line with the four ticks and asked to point to its two end points (zero and 100) to ensure that they considered the entire line. The examiner pointed at the four ticks and then presented the number, asking subjects to point to the tick corresponding to the value of the number. Correct and erroneous responses received 2 and zero points, respectively.

Writing down an operation

Depending on the particular arithmetical operation, the two operands need to be arranged according to precise conventional rules (e.g., for multiplication, the two numbers should be written one above the other, justified to the right and digits aligned into columns, but not for division). There was one item for each of the four basic operations. The two operands were presented on a single horizontal line, the name of the operation and of the arithmetical sign was indicated in orthographic form, and the whole was read aloud by the examiner. Emphasis was put on the operations. Subjects had to copy the two numbers and arrange them appropriately.

Written calculation

Subjects were asked to work silently. They could write intermediate results, or reconstruct arithmetic tables on the sheet of paper. For multiplications, each intermediary product (two and three lines of numbers for the first and second item, respectively) was scored 1 point when correct and zero otherwise. Moreover, for each item, the whole correct spatial arrangement of the results (left displacements) was scored 1. Under such scoring conventions, maximum score was 3 and 4 for the first and second item, respectively, which made a total of 7 points. The final result, that is, the addition of intermediary products, was not considered for scoring since additions were evaluated in Subtest 26 above and the current subtest intended to specifically assess multiplication procedures.

Perceptive estimation of quantities

The subtest contains a total of six items for the estimation of weights, heights and quantity. In order to encourage subjects to perform rapid estimations, they were instructed that pictures would be presented during a short period of time (5 s). The distribution of responses provided by controls was analyzed, and the 5% values situated at the two extremes of the statistical distribution were scored zero points, whereas the 90% central values received 2 points per item.

Contextual magnitude judgments

The subtest contains five items. The stimuli were constructed in such a way that, depending on their contexts, numbers may receive semantic interpretations in reverse direction to that indicated by their arithmetical values, or the same number may receive different semantic values.

Precise numerical knowledge

The subtest contains six questions involving well-known numerical facts. Items were presented orally and written on a sheet of paper; subjects responded in their preferred mode (spoken verbal or Arabic numerals) without prejudice on the score.

RESULTS

Normative Data

For 10 tasks (c2, c3, c4, c5, c9, c11, c13, c16, c17, and c31) a clear ceiling effect was observed: the proportion of subjects who obtained the maximum score was greater than 97% in the whole sample, and with one exception (task c16, Italy, educational level 5, 85% of complete success) this proportion was greater than 90% in all 10 country by educational level subgroups (see Appendix 2). No further analysis was performed for these 10 tasks.

For the 21 other tasks a regression analysis was performed, with the General Linear Models (GLM) procedure of SAS software, with the score at each task as the dependent variable, and age (continuous), gender, country and education (four levels for Italy and three levels for France and Germany) as explanatory variables. Two analyses were performed with and without exclusion of the 40 subjects from Italy with very low education (on $n = 551$ and $n = 511$ subjects, respectively). The age effect never reached statistical significance. Gender effect was significant for three tasks (c8, c20, c21) in the first analysis (p between .05 and .01) and for only one task (c8) in the second, with better performance in men than women. When the total score was considered, both a gender effect ($F = 8.36$, $df = 1{,}543$, $p = .004$) and a strong Age × Educational level interaction ($F = 8.76$, $df = 3{,}540$, $p < .001$) were observed in the first analysis but not in the second. As Figure 1 shows, a clear advantage of men over women was only observed in the very low educational group from Italy. The country effect was similar in both analyses (total score: first analysis: $F = 17.86$, $df = 2{,}543$, $p < .001$; second analysis: $F = 22.60$, $df = 2{,}504$, $p < .001$) and significant for 16 of the 21 tasks. Figure 2 shows the mean performance by task and country. For counting tasks (c1, c6, c7) and oral calculation (c20) performance was lower in France. For the other tasks, the dominant pattern demonstrated the best results in Germany and the lowest results in Italy. The main difference was

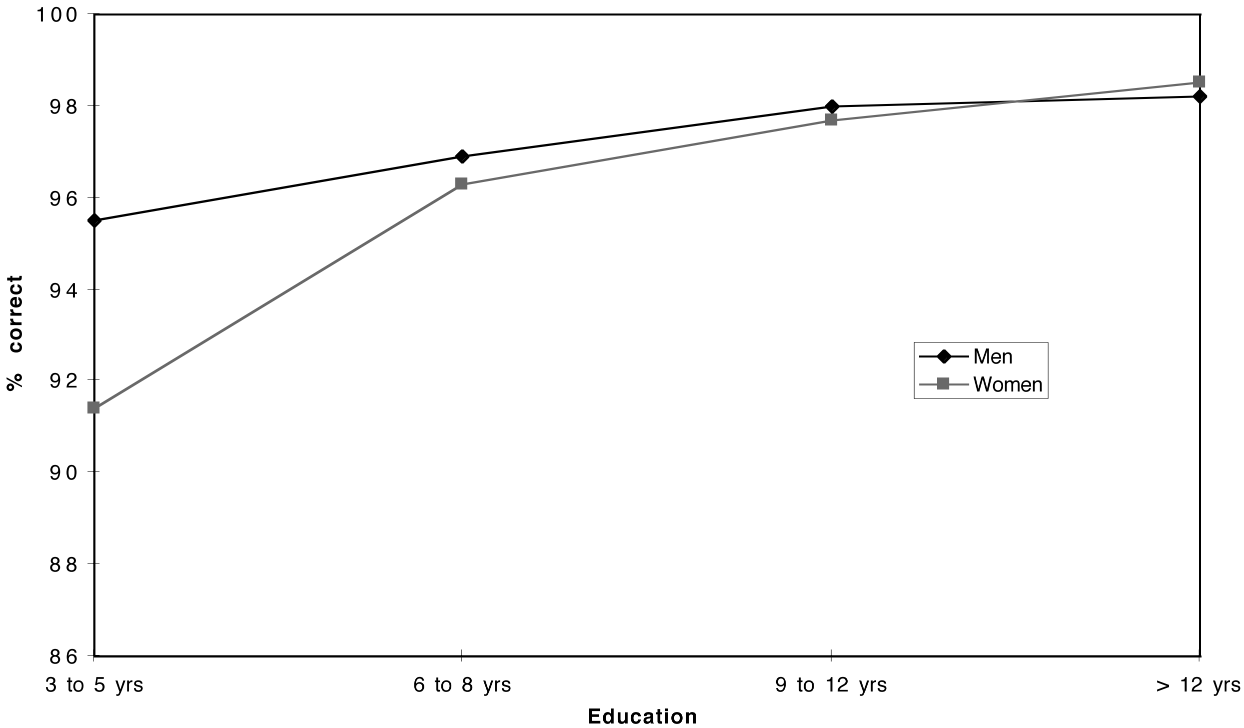

Fig. 1. Total score by gender and education.

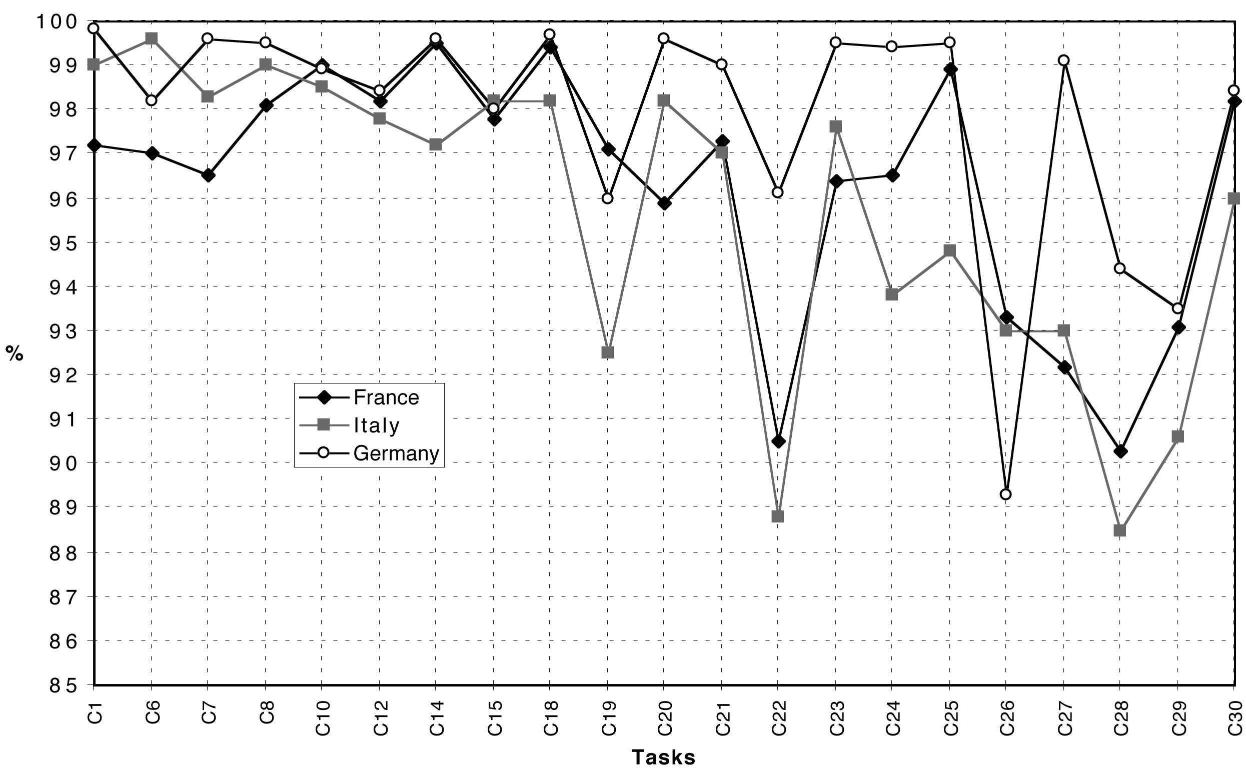

Fig. 2. Percent correct at each task by country. The figure shows the mean performance at each task in France (n = 180), Italy (n = 172) and Germany (n = 159). For all tasks except C8, C10, C12, C15 and C26, the means differed significantly between the three countries : $p < .001$ for C1, C14, C19, C20, C22, C24, C25; $p < .01$ for C6, C7, C18, C23, C27, C28, C30; $p < .05$ for C21, C29.

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between Germany and the two other countries for some tasks (c21, c22, c23, c27, c28); between Italy and the two other countries for other tasks (c14, c18, c19, c25, c29, c30). As expected, the adjusted educational level effect was overall stronger in the first analysis (four levels of education) than in the second (three levels), however results of both analyses were very close (total score: first analysis: $F = 30.15$, $df = 3{,}543$, $p < .001$; second analysis: $F = 24.92$, $df = 2{,}504$, $p < .001$). Education was significant for 12 of the 21 tasks in both analyses (i.e., no education effect for c6, c7, c8, c18, c23, c24, c25, c26 and c29), for two tasks in the first only (c18, c24) and for one task in the second only (c23). The dominant pattern was as expected: the higher the educational level the better the performance. However results of the two highest educational groups were generally close (Fig. 3).

Appendix 3 shows the observed tenth percentile for each task by country and educational level. Appendix 4 summarizes the observed distribution of the total score by country, educational level, and gender.

CVA Patients

A first analysis compares the mean performance at each of the 31 subtests between the groups of normal French controls ($n = 180$), LBD patients ($n = 56$) and RBD patients ($n = 24$). The results are summarized in Figure 4. The overall group effect was significant for all tasks. Mean performance of the LBD group was significantly lower than that of controls for all tasks except three, and mean performance of the RBD group was lower than that of controls for 10 tasks.

Secondly, regression analyses were performed within the brain-damaged group, with performance at each task as the dependent variable and age (continuous), delay between occurrence of CVA and investigation (continuous), laterality of CVA (right or left), gender, educational level (three levels) and hemiplegia (presence or absence) as explanatory variables. Table 3 shows that the main significant effect is laterality of CVA, which is almost equivalent in this sample to presence or absence of aphasia (see Table 2b). For only 10 of the 31 tasks was the effect of laterality of brain damage not significant. For one task only (c23), performance was better in LBD than in RBD patients. For the other 20 tasks performance was better in RBD than LBD patients (Fig. 4). Appendix 5 presents details of the distribution of the scores in right and left CVA groups. The remaining other explanatory variables showed occasionally a significant effect. Gender effects with a consistent advantage for women were observed for 6 tasks and for the total score; however this effect was only at $.01 < p < .05$ level and (even adjusted) should be considered with caution given

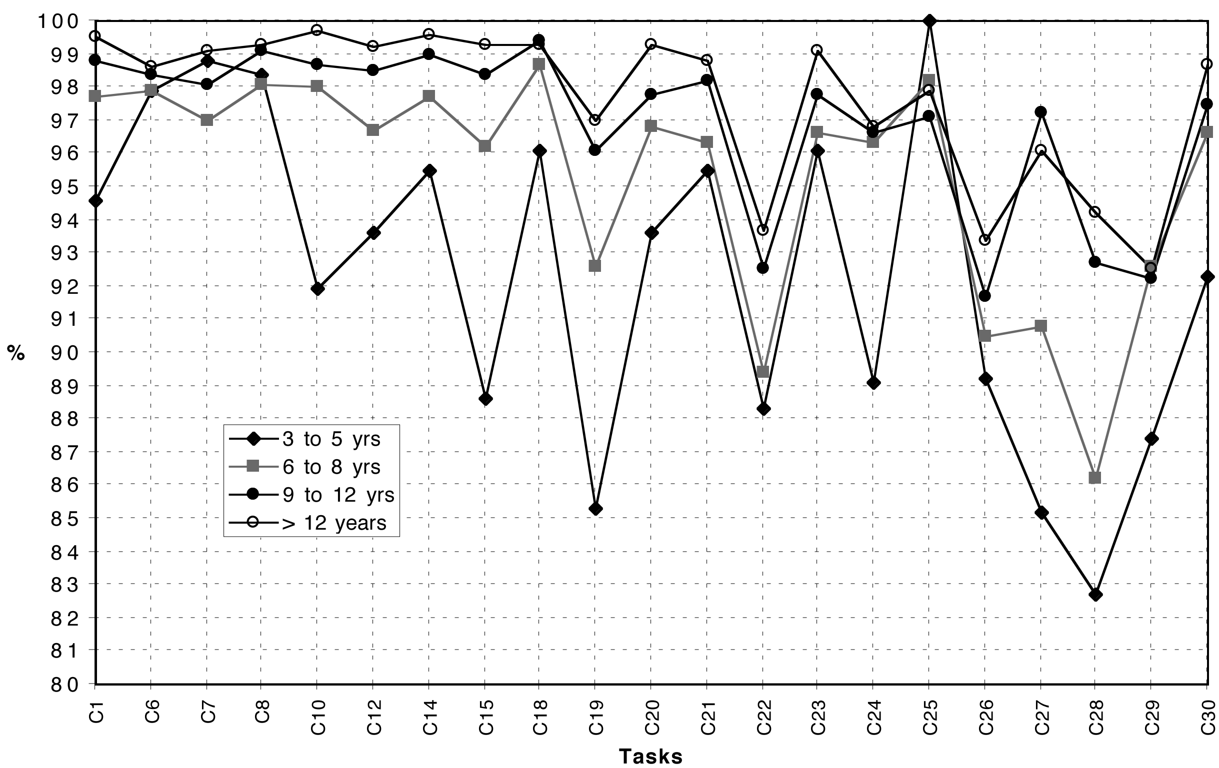

Fig. 3. Percent correct at each task by education. The figure shows the mean performance at each task by education: 3 to 5 yrs ($n = 40$); 6 to 8 yrs ($n = 171$); 9 to 12 yrs ($n = 171$); more than 12 yrs ($n = 169$). The differences between the four levels of education are significant for all tasks except C6, C7, C8, C23, C25, C26 and C29; $p < .05$ for C22; $p < .01$ for C21; $p < .001$ for C1, C10, C12, C14, C15, C18, C19, C20, C27, C28, C30.

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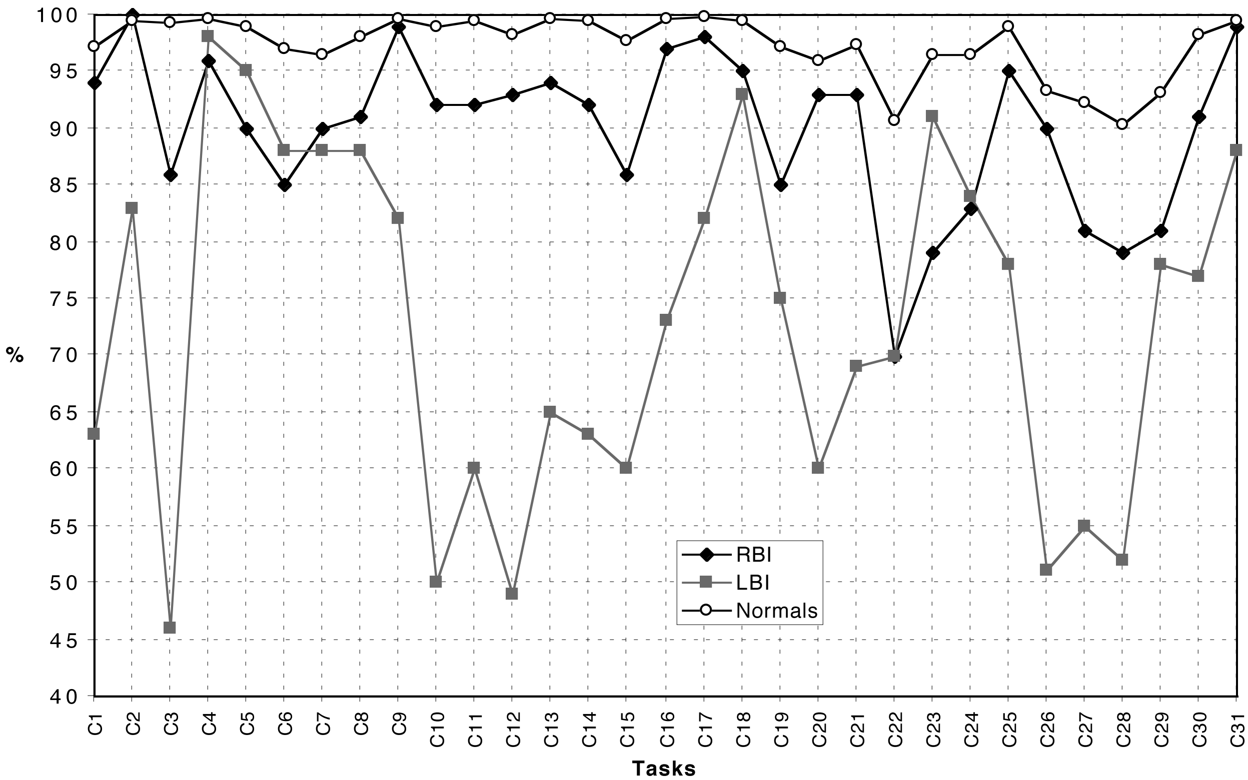

Fig. 4. Percent correct by task in patients with Right (RBI) and Left (LBI) Hemisphere CVA. The figure shows the mean performances at each task in patients with Right Brain Injury ($n = 24$), Left Brain Injury ($n = 56$) and Normal French Controls ($n = 180$). For all tasks means differed significantly between the three groups at $p < .001$ ($p < .01$ for C4). Post-hoc pairwise comparisons of the means showed: (i) significant difference between LBD patients and controls for all tasks except C4, C5, C23; (ii) significant difference between RBD patients and controls for the ten following tasks: C3, C4, C5, C6, C15, C19, C22, C23, C24, C29; (iii) significant difference between LBD and RBD patients for all tasks except C4, C6, C7, C8, C18, C22, C24, C29; C23 is the only task for which LBD patients performed better than RBD patients.

the unequal distribution of gender in right and left CVA groups. There was no consistent effect of educational level. Presence of hemiplegia tended to have a negative effect on number comparison (c18, c19) and on positioning orally presented numbers on a scale (c24). Old age had a negative effect in 4 tasks, particularly comparison of numbers presented alphabetically (c19) and contextual estimation of quantities (c30). Finally long delay from CVA occurrence tended to show a small negative effect for four tasks (c3, c20, c22, c27), three of them involving calculation or estimation of the result of an operation (c20, c22, c27). The latter is not necessarily a real delay effect, as long delay might be associated with greater initial impairment.

Summary of the Results by Task

Counting

Normal subjects, even of low education, performed at a ceiling level on simple written Arabic digit counting (c2) and on simple written orthographic counting (c3). For the more complex parts of spoken verbal counting (c1), that is, by threes, by tens and counting backwards, an expected education effect was observed, with presence of errors among subjects with low or very low education, but also a more unexpected effect of the country, with more errors among French than among Italian or German subjects. In brain-damaged patients, writing the sequence of digits (c2) is well preserved, even in the case of aphasia, with few exceptions. Spoken verbal counting (c1) is almost perfect in RBD patients but deficient in many subjects with aphasia. Written orthographic counting (c3) is performed less well by RBD patients than by controls and is very frequently deficient in LBD patients. Despite the fact that spoken verbal counting included more complex tasks (i.e., counting by threes and counting backwards) than orthographic counting, the performance of aphasic patients was lower for the latter than for the former.

Dot counting

Normative data show that most enumeration tasks were performed at a ceiling level and it is worth noting that no education effect was observed. For medium size sets with nonlinear arrangements (c6, c7), the curious tendency of French participants to make mistakes is in agreement with

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Table 3. Effects of laterality of the lesion, gender, education, hemiplegia, age and delay post-injury on the performance at each task in CVA patients

Task	Right/Left hem. inj.	Gender	Education[1]	Hemiplegia	Age[2]	Delay post-inj.[2]
C1	R>L**	W>M*				
C2						
C3	R>L***					
C4						r<0*
C5						
C6						
C7						
C8						
C9	R>L*					
C10	R>L***					
C11	R>L**	W>M*				
C12	R>L***					
C13	R>L**	W>M*				
C14	R>L**					
C15	R>L**				r<0*	
C16	R>L**					
C17	R>L*					
C18				no>yes*		
C19	R>L*		2>3>1*	no>yes**	r<0**	
C20	R>L***					r<0*
C21	R>L***					
C22						r<0*
C23	L>R*					
C24		W>M*		no>yes**		
C25	R>L**				r<0*	
C26	R>L***					
C27	R>L*		2>3>1*			r<0*
C28	R>L***	W>M*				
C29						
C30	R>L*				r<0**	
C31	R>L*	W>M*				
Total	R>L***	W>M*				

Note. Results of the linear regression model (GLM procedure of SAS).
$*p < .05$; $**p < .01$; $***p < .001$.
1: 1 = 5–8 years; 2 = 9–12 years; 3 = >12 years.
2: Performance decreases with age or delay post-injury when significant.

their imperfect performance in oral counting and oral mental calculation. On linear arrangements, a significant tendency for women to show more errors than men was observed, and this was the only task where a sex difference was observed in normals after exclusion of the very low education group. Dot counting was passed remarkably well by CVA patients, with no differences between the left- and the RBD. Performance was almost perfect on dominoes (where a subitizing procedure is very likely) and only slightly lower than that of controls for the other dot-enumeration tasks. Results suggest that in some LBD patients, enumeration in small sets (<13 elements) may be preserved despite errors in spoken verbal counting.

Transcoding

In normals, oral repetition and reading of the digital and orthographic code were almost perfectly passed. A significant education effect was observed for all the other numerical transcoding tasks. Italian subjects showed more errors on writing digital numbers under dictation. LBD patients performed lower than RBD patients on all transcoding tasks, the difference being smaller for repetition than for the other tasks. The performance of right-brain damaged patients was perfect for repetition and only slightly lower than that of controls for the other transcoding tasks.

Arithmetical signs

Naming and writing under dictation of the four arithmetical signs (i.e., +, −, ×, =) were almost perfectly performed by normal subjects and by RBD patients. On the contrary, many aphasic patients showed errors on these simple tasks, more on naming than on dictation.

Number comparison

A significant country effect was observed in normals, with lower results in Italy than in France and Germany. Education had a significant effect; for the digital presentation (c18), the main difference was between the very low educational group from Italy and the three other groups; for the orthographic presentation (c19), the effect persisted after exclusion of the very low Italian educational group. The effect of brain injury was related to the presentation of the numbers: almost normal performance in the digital presentation even among aphasic patients; low performance of aphasic patients and intermediate performance of RBD patients in the alphabetical presentation.

Mental calculation

Significant differences between countries were observed for mental calculation, with higher performances in Germany than in France and Italy. For oral mental calculation (c20) French subjects performed lower than Italian subjects. The effect of education remained significant even after exclusion of the very low educated group. Men did better than women in the very low educated group only. Performance of RBD patients was close to normal, but that of LBD patients was clearly lower.

Approximating the result of an operation

German subjects succeeded much better at this task than French and Italian subjects. The education effect was significant. Performance of brain-damaged subjects was lower than that of controls and identical in LBD and RBD patients.

Placing a number on an analogue scale

Differences between countries were significant with higher performance in Germany and, for the oral presentation (c24), lower performance in Italy. The very low educated group performed poorly in oral presentation (c24) but relatively well in written presentation (c23). Placing a written number on an analogue scale was the only task in which aphasic patients (i.e., with left-brain damage) performed significantly better and at a close to normal level than RBD. In the oral presentation RBD and LBD subjects performed equally and significantly lower than controls.

Placing multidigit numbers to perform an operation

Only a country effect was observed, with perfect success in Germany and in France but not in Italy. No significant education effect was observed; it is worth noting that all very low educated subjects (but not all subjects with higher education) performed this task perfectly. Contrary to the expectation related to the possible presence of 'spatial dyscalculias' (Hécaen et al., 1961), results of RBD patients were close to normal, and those of LBD subjects were significantly lower.

Written calculation

Country and education effects were not significant for additions (c26) but were significant for subtractions (c27) and multiplications (c28), with higher performances in Germany. RBD subjects performed close to normals for additions but lower for subtractions and multiplications. In all three written calculation subtests, results of LBD subjects were lower than those of RBD subjects.

Magnitude approximations of pictured stimuli

A slight country effect was observed with lower performance in Italy. No significant difference was observed according to the laterality of the lesion, both groups of brain-damaged patients performing slightly lower than controls.

Contextual magnitude judgments

Results were lower in Italy and in the very low educated group and lower in LBD than RBD patients.

Precise numerical knowledge

Normals and RBD patients showed a ceiling effect at this task but results in LBD subjects were significantly lower.

DISCUSSION

The normative data produced show which elementary calculation and number processing tasks are strongly dependent on educational level and which are not. The findings also suggest that there are important differences in performance even between Western European countries, which should be taken into account in neuropsychological assessment. Normal adult subjects from Germany, Italy and France with at least 3 years of schooling are expected to perform perfectly at 10 of the 31 subtests. Presence of errors at these tasks in brain-damaged patients with at least 3 years of schooling can be considered pathological. For all of the other tasks of the EC301 battery an education effect and/or a country effect was observed. For these tasks the 10th percentile presented by country and educational level (Appendix 3) is recommended as the cut-off point.

The effect of education was significant for complex parts of spoken verbal counting (c1), i.e., by threes, by tens and counting backwards; number transcoding involving a written (but not an oral) response; number comparison especially in alphabetical presentation; mental calculation; written subtractions and multiplications (but not additions). Subjects in the lowest educational group showed specific difficulties with comparison of numbers presented in the digital code and with placing numbers on an analogue number line when presentation of the numbers to be placed was oral. These results suggest both an expected increasing familiarity with writing numbers and performing calculations and arithmetic operations with educational level and a reduced ability to use analogue scales and compare numbers among

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subjects with a low educational level. Also, very low educated subjects, but not all subjects with higher education, performed perfectly on placing multidigit numbers in order to carry out an operation. This suggests that the rules of how to organize the numbers spatially on a sheet of paper to perform the four basic arithmetical operations were more scrupulously respected by subjects with low familiarity with written calculations. The above results are consistent with previous investigations showing that the role of formal education may be quite different according to the specific number- or calculation-related task under consideration. For instance, completely unschooled normal Brazilian subjects show quite respectable performance in counting the number of elements in small sets but in other numerical tasks not obviously related to literacy, such as digit span or counting backwards, their performance may be quite close to that of some brain-damaged literates (Deloche et al., 1999a).

Important differences were observed between the three countries, which could be attributed either to the different educational systems or to linguistic factors. German subjects performed particularly well compared to the two other countries on the most elaborate calculation subtests, namely, mental calculation, estimation of the result of an operation, positioning a number on a scale, subtractions and multiplications. Results of French subjects were characterized by more errors than that of Italian and German subjects on subtests of verbal counting, enumeration of dots and mental calculation. Results of Italian subjects were relatively low for subtests involving magnitudes, i.e., number comparison and estimation of quantities. Linguistic factors, such as special complexities of the French verbal code for numbers (e.g., 70 is *soixante-dix*, i.e., sixty-ten; 80 is *quatre-vingts*, i.e., four-twenty), could possibly be involved in the counting and calculation problems of French-speaking subjects. However linguistic factors can hardly explain the other results. In tasks such as transcoding for instance, there was no advantage for Italian subjects who have the most regular linguistic system for numbers. A previous study comparing German-speaking Swiss schoolchildren with French-speaking schoolchildren of second and third grade also showed higher performance of the German-speaking on calculation (Von Aster et al., 1997). However, the same study also showed a disadvantage of the German compared to the French-speaking children in writing Arabic numbers from dictation. The latter difference was attributed to the irregular left-to-right correspondence between spoken verbal forms and Arabic digit strings in German (e.g., 35 is “five-thirty”) but not in French (35 is “thirty-five”). The overall pattern of results could suggest that, for German-speaking people, this initial difficulty in childhood becomes an advantage in adulthood.

Variations according to age were not observed. The absence of any significant age effect is possibly related to the absence of subjects older than 70 years and to the elementary aspect of the tasks. Previous studies of possible age effects on simple arithmetics in normal adults indicate controversial results: no role of age on performance levels (Deloche et al., 1994, 1999b; Jackson & Warrington, 1986; Villardita et al., 1985), or effect in terms of speed of processing, but younger adults perform better than older adults or the contrary depending on the type of numerical activities (Geary & Lin, 1998).

A slight male advantage was observed mainly among participants of the lower educational level especially for calculation. Gender effects have often been reported in the area of calculation. In children, an initial advantage of girls over boys in elementary and middle school has been reported. However, this might be reversed in high school and college with women performing less well than men (see Hyde et al., 1990, for a meta-analysis). In normal adults, complex interactions have been reported between gender, type of attitude of the experimenter giving instructions (i.e., positive, neutral, negative), and noise condition (i.e., quiet, noisy) on subjects’ accuracy and speed in mental arithmetic (Gulian & Thomas, 1986). The Gender $\times$ Educational Level interaction observed in the present study is in agreement with previous investigations showing a clear advantage of males over females among unschooled or very low-educated subjects, but no gender effect in samples with medium or high educational levels (Deloche et al., 1999a, 1999b; Rosselli et al., 1990).

In brain-damaged patients no ceiling effects were observed, with very few exceptions. Sex differences, if any, were inversed compared to sex differences in normals. Some age effects were observed, contrary to results in normals. Finally, the education effect was absent or inconsistent. Overall, brain-damage related factors were much more important than individual factors and interactions between the former and the latter can not be excluded. These potential interactions might be important for the design of studies comparing groups of brain-damaged patients. For instance, it might be important to have equal ages between the groups when comparing them on calculation performance, despite the absence of a significant age effect on calculation performances in normals.

The application of the EC301 in patients with stroke aimed to present an overview of preserved and impaired calculation and number processing abilities in LBD aphasics and RBD nonaphasics. Performances of patients with CVA clearly show that there is a strong deleterious effect of left-hemisphere injury and aphasia on most of the tasks involving calculation and number processing. On the contrary, patients with right-hemisphere injury show a relatively well preserved ability to deal with numbers. However, this overall advantage of patients with RBD varies dramatically according to the specific task considered and might even be reversed. Patients with LBD show particularly low performance on oral and alphabetical counting, transcoding when a written code (digital or alphabetical) is involved, and mental or written calculation. On the contrary, LBD patients show good performance at counting dots whatever their display, comparing numbers written in the digital code, placing correctly a number on an analogue number line, especially when the presentation of the number is written, and giving the correct number of days in a week, months in a year, minutes in an hour, etc. In RBD patients, the lowest performances were observed for the estimation of the result of an operation, placing a number on a scale, and perceptual estimation. In RBD patients a discrepancy can be noticed between good performance in simple mental calculation and positioning an operation, and relatively low performance in more complex written subtractions and multiplications. LBD performed significantly better than RBD patients for only one task: placing correctly numbers on a scale with written presentation of the numbers to be positioned.

The level of performance among aphasic patients confirms the presence of dissociations between impaired number processing when numbers are spoken or written alphabetically and relatively well preserved number processing when numbers are in Arabic forms, which is consistent with the *triple code* model of Dehaene (1992). Counting showed noteworthy resistance to unilateral vascular brain damage, which is possibly related to the 'primary' or 'natural' characteristic of this task (e.g., completely unschooled subjects show a remarkable ability to count; Deloche et al., 1999a); it could be explained by some 'innate' ability for counting (Gelman & Gallistel, 1978) and by the many possible ways of achieving correct counting when facing small sets of numbers (e.g., counting, subitizing, estimation). Further investigation is needed to make clearer how specific aphasic syndromes affect or not the different components of number processing and calculation. A first step in this direction is the recent study by Basso et al. (2000) using the EC301 battery, which did not find a significant difference between Broca and Wernicke aphasics. In conclusion, to understand the role of language in calculation, continuing the investigation of calculation in aphasics could be equally and even more effective than functional brain imagery in normals.

Another question raised by the present study is the relationship between visuospatial skill and the analogical representation system of numbers postulated by Dehaene (1992). Findings show evidence that estimation, magnitude comparison and approximation might be impaired by lesions of either cerebral hemisphere, as expected (Dehaene & Cohen, 1995; Noel & Seron, 1993), and also that the analogical representation of numbers on a scale might be specifically impaired in RBD patients. The latter observation was expected, as it is well known that visual neglect and perceptual or representational distorsions of space are associated with right-hemisphere dysfunction. The tasks of number positioning on a zero to 100 scale, can be assimilated to expanded versions of the popular line-bisection tasks, used for the detection of visual neglect, in which "put the 50" is required only. However, there was no evidence for a strong relationship between performance at positioning numbers on a scale and performance at estimation, approximation or magnitude comparison. In a principal component analysis performed within the brain-damaged group (results not shown), estimation tasks and scale tasks generated different factors. This observation is in agreement with the conclusion of Basso et al. (2000) that the relationship between spatial and calculation disorders in RBD patients is not perfectly clear. Further investigation is needed to explore possible functional links between visuospatial skill and analogical representation of numbers.

Taken together, these results and findings indicate the usefulness of the EC301 battery for the evaluation of the patterns of preserved and impaired numerical abilities following brain injury, a cognitive area that requires reference to precise normative data. Besides such clinical application, the battery is also of interest for cross-cultural studies.

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Appendix 1

THE CALCULATION AND NUMBER PROCESSING BATTERY: CONTENT OF THE 31 SUBTESTS

Number Sequences

C1: Spoken Verbal Counting: (1) from 1 to 31; (2) by threes from 3 to 21; (3) by tens from 10 to 90; (4) backwards from 22 to 1.
C2: Arabic Digit Counting: from 1 to 31.
C3: Writen Verbal Counting: (1) from one to sixteen; (2) by tens from ten to ninety.

Dot Counting

C4: Small sets on Dominoes: 6, 4, 5 dots.
C5: Small sets on random arrangements: 4, 6, 5 dots.
C6: Medium sets on segmentable arrangements: 11, 8, 10 dots.
C7: Medium sets on random arrangements: 10, 8, 11 dots.
C8: Medium sets on linear arrangements: 9, 7, 12 dots

Transcoding

C9: Oral repetition of numbers: 1630, 8012, 400000, 116, 785, 52319
C10: From Arabic to Written Verbal, (example given: 2-two): 1450, 9011, 500000, 114, 387, 62718.
C11: Reading Arabic numerals (e.g., 2): 1360, 4015, 900000, 113, 281, 35617.

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C12: Writing Verbal numbers from dictation (e.g., two): the same six numbers as in C9.
C13: Reading Written Verbal numbers (e.g., two): as in c11.
C14: Writing Arabic numerals from dictation (e.g., 2): as in c9.
C15: From Written Verbal to Arabic (e.g., 2): as in c10.

Arithmetical Signs

C16: Naming =, ×, −, +.
C17: Writing =, +, ×, − from dictation.

Number Comparison

C18: Pairs of Arabic numerals (e.g., 1 *vs*. 1000): 122 *vs*. 87; 2005 *vs*. 200005; 536 *vs*. 546; 865 *vs*. 217; 300313 *vs*. 13316; 20045 *vs*. 20405; 329 *vs*. 325; 1102 *vs*. 100002.
C19: Pairs of Written Verbal numbers (e.g., one *vs*. one thousand): 300000 *vs*. 100065; 12000 *vs*. 1050; 769 *vs*. 2035; 87 *vs*. 101; 1032 *vs*. 648; 16014 *vs*. 20030; 110 *vs*. 700; 69000 *vs*. 35000.

Mental Calculation

C20: Spoken numbers: 5 + 8; 9 + 7; 7 × 4; 3× 8; 17 − 5; 14 − 6; 18 ÷ 3; 16 ÷ 2
C21: Arabic numerals: same as C20.

Estimation of the Result of an Operation

C22: (Example given: 190 × 2= *400*, 40, 200, 800). (1) 275 × 4 = 600, 1200, 2300, 50. (2) 145 × 3 = 700, 1400, 100, 400. (3) 545 + 325 = 1700, 500, 900, 200. (4) 875 + 745 = 1600, 100, 800, 3200. (5) 710 ÷ 3 = 2200, 100, 500, 250. (6) 460 ÷ 3 = 100, 1400, 150, 300. (7) 1520 − 780 = 2300, 1450, 400, 700. (8) 745 − 375 = 800, 400, 1200, 200.

Number Positioning on a Zero to 100 Vertical Scale

C23: Placing Arabic numerals (e.g., 56): 86, 48, 32, 5, 62.
C24: Placing spoken numbers: 6, 47, 33, 87, 61.

Writing Down an Operation

C25: 435 plus 86; 517 divided by 43; 816 multiplied by 19; 908 minus 71.

Written Calculation (Operands Arranged According to the Conventional Rules)

C26: 708 + 494; 458 + 697.
C27: 473 − 245; 920 − 612.
C28: 324 × 12; 687 × 405.

Perceptive Estimation of Quantity (Six Pictures, Interval of ‘Correct’ Answers in Brackets)

C29: (1) a person, weight? (70–94 Kg); (2) an umbrella, weight? (200g–1.5 Kg); (3) a traffic light, height? (1.5–4.5 m); (4) a plant, height? (50 cm–1 m); (5) a picture of about 60 corks, how many? (20–100); (6) a picture of about 80 small bottles, how many? (30–130).

Contextual Magnitude Judgments (‘Correct’ Answers in Brackets)

C30: Example: Four WC in an apartment is ‘a lot’; ten spectators in the cinema is ‘few’; (1) twenty pages for a letter (a lot); (2) nine children for a school (few); (3) 35 passagers in a bus (medium); (4) 8 plates for a restaurant (few); (5) 9 children for a mother (a lot).

Precise Numerical Knowledge

C31: How many (1) days in a week; (2) legs on a chair; (3) minutes in an hour; (4) fingers on one hand; (5) wheels on a car; (6) months in a year.

Appendix 2

PERCENT OF PARTICIPANTS WITH THE MAXIMUM SCORE BY COUNTRY AND EDUCATION

	France			Italy				Germany				
Subtest	1* *n* = 60	2* *n* = 60	3* *n* = 60	0* *n* = 40	1* *n* = 59	2* *n* = 58	3* *n* = 55	1* *n* = 52	2* *n* = 53	3* *n* = 54	Total 1 511	Total 2 551
C1	78.3	90.0	96.7	82.5	93.2	96.5	98.2	100	98.1	100	94.3	93.5
C2	96.7	100	100	97.5	100	100	100	100	100	100	99.6	99.5
C3	96.7	98.3	100	97.5	98.3	100	96.4	100	100	100	98.8	98.7
C4	96.7	100	98.3	92.5	100	98.3	96.4	100	100	100	98.8	98.4
C5	100	93.3	96.7	97.5	98.3	100	96.4	98.1	100	100	98.0	98.0
C6	90.0	93.3	90.0	97.5	98.3	98.3	100	92.3	92.4	98.1	94.7	94.9
C7	88.3	90.0	96.7	95.0	88.1	96.5	94.5	98.1	98.1	100	94.3	94.4
C8	95.0	96.7	96.7	95.0	93.2	98.3	98.2	98.1	98.1	100	97.1	96.9
C9	96.7	96.7	100	92.5	100	94.8	100	100	100	100	98.6	98.2
C10	88.3	95.0	100	70.0	88.1	94.8	100	96.1	94.3	94.4	94.5	92.7
C11	95.0	95.0	98.3	90.0	94.9	98.3	98.2	98.1	100	100	97.8	97.3
C12	76.7	85.0	93.3	55.0	67.8	86.2	87.3	76.9	90.6	94.4	84.1	82.0
C13	93.3	100	100	95.0	96.6	100	100	96.1	98.1	100	98.2	98.0
C14	98.3	96.7	98.3	77.5	71.2	86.2	90.9	92.3	98.1	100	92.4	91.3
C15	78.3	90.0	98.3	60.0	86.4	91.4	92.7	78.8	92.4	96.3	89.4	87.3
C16	98.3	100	100	85.0	96.6	100	98.2	100	100	100	99.2	98.2
C17	98.3	100	100	92.5	96.6	100	100	100	100	100	99.4	98.9
C18	93.3	98.3	95.0	77.5	83.0	91.4	87.3	92.3	100	100	93.3	92.2
C19	68.3	85.0	91.7	27.5	54.2	60.3	70.9	59.6	79.2	83.3	72.6	69.3
C20	71.7	71.7	88.3	67.5	89.9	84.5	92.7	94.2	96.2	100	87.3	85.8
C21	80.0	83.3	90.0	75.0	79.7	89.7	90.9	86.5	94.3	100	88.1	87.1
C22	56.7	63.3	71.7	37.5	45.8	62.1	60.0	73.1	77.4	81.5	65.4	63.3
C23	80.0	91.7	96.7	87.5	89.8	87.9	89.1	94.2	100	100	92.0	91.7
C24	83.3	88.3	91.7	40.0	71.2	70.7	67.3	98.1	96.2	96.3	84.5	81.3
C25	98.3	93.3	96.7	90.0	89.8	87.9	87.3	98.1	100	100	94.5	94.2
C26	85.0	90.0	90.0	85.0	83.0	86.2	89.1	78.8	75.5	81.5	84.5	84.6
C27	76.7	91.7	90.0	75.0	81.4	94.8	89.1	96.1	98.1	100	90.6	89.5
C28	56.7	70.0	65.0	50.0	49.2	63.8	72.7	71.1	75.5	92.6	68.1	66.8
C29	66.7	58.3	81.7	35.0	61.0	60.3	49.1	65.4	71.7	59.3	63.8	61.7
C30	88.3	91.7	95.0	65.0	79.7	81.0	89.1	84.6	92.4	100	89.0	87.3
C31	98.3	93.3	96.7	92.5	96.6	100	100	94.2	100	98.1	97.5	97.1
Total	3.3	13.3	18.3	2.5	3.4	3.4	12.7	7.7	18.9	24.1	11.5	10.9

Note. *Education: 0 = less than 5 years; 1 = 5 to 8 years; 2 = 9 to 12 years; 3 = more than 12 years.

Appendix 3

TENTH PERCENTILE BY COUNTRY AND EDUCATIONAL LEVEL FOR EACH TASK

		France			Italy				Germany		
Task	Max	1* *n* = 60	2* *n* = 60	3* *n* = 60	0* *n* = 40	1* *n* = 59	2* *n* = 58	3* *n* = 55	1* *n* = 52	2* *n* = 53	3* *n* = 54
C1	8	6	7	8	6	8	8	8	8	8	8
C2	2	2	2	2	2	2	2	2	2	2	2
C3	4	4	4	4	4	4	4	4	4	4	4
C4	6	6	6	6	6	6	6	6	6	6	6
C5	6	6	6	6	6	6	6	6	6	6	6
C6	6	5	6	5	6	6	6	6	6	6	6

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Appendix 3 continued

		France			Italy				Germany		
Task	Max	1* n = 60	2* n = 60	3* n = 60	0* n = 40	1* n = 59	2* n = 58	3* n = 55	1* n = 52	2* n = 53	3* n = 54
C7	6	4	5	6	6	5	6	6	6	6	6
C8	6	6	6	6	6	6	6	6	6	6	6
C9	12	12	12	12	12	12	12	12	12	12	12
C10	12	10	12	12	8	10	12	12	12	12	12
C11	12	12	12	12	11	12	12	12	12	12	12
C12	12	10	11	12	10	10	11	11	10	12	12
C13	12	12	12	12	12	12	12	12	12	12	12
C14	12	12	12	12	8	10	11	12	12	12	12
C15	12	10	11	12	8	10	12	12	10	12	12
C16	8	8	8	8	6	8	8	8	8	8	8
C17	8	8	8	8	8	8	8	8	8	8	8
C18	16	16	16	16	12	14	16	14	16	16	16
C19	16	12.5	14	16	10	12	12	14	14	14	14
C20	16	12	14	14	13	15	14	16	16	16	16
C21	16	14	14	15	12	12	14	16	14	16	16
C22	16	9	10	12	10	10	10	8	12	14	14
C23	10	8	10	10	8	8	8	8	10	10	10
C24	10	8	8.5	10	8	8	8	6	10	10	10
C25	8	8	8	8	7	6	6	2	8	8	8
C26	4	2	3	3	2	2	2	2	2	2	2
C27	4	2	4	3	1	2	4	5	4	4	4
C28	7	3.5	5	5	4	4	5	8	6	6	7
C29	12	10	8	10	8	8	10	8	10	10	10
C30	10	8	10	10	8	8	8	12	8	10	10
C31	12	12	12	12	12	12	12	12	12	12	12

Note. *Education: 0 = less than 5 years; 1 = 5 to 8 years; 2 = 9 to 12 years; 3 = more than 12 years.

Appendix 4

DISTRIBUTION OF THE TOTAL SCORE BY COUNTRY, EDUCATIONAL LEVEL AND GENDER

	N	*M*	*SD*	Range	*MDN*	10%
France						
edu. 5–8 yrs						
Women	30	286.0	12.6	248–301	289	269
Men	30	292.2	6.6	270–301	294	284
edu. 9–12 yrs						
Women	30	292.7	7.0	269–301	295	282
Men	30	293.8	7.5	262–301	295	287
edu. >12 yrs						
Women	30	296.4	3.6	289–301	296	291
Men	30	297.0	3.3	288–301	297	293
Italy						
edu. <5 yrs						
Women	20	272.9	18.4	222–293	279	242
Men	20	286.7	12.0	256–301	288	268
edu. 5–9 yrs						
Women	30	287.0	15.0	228–300	289	271
Men	29	289.8	11.0	257–301	293	266
edu. 9–12 yrs						
Women	29	291.9	8.2	265–301	294	280
Men	29	293.2	5.7	278–301	295	284
edu. >12 yrs						
Women	28	294.2	5.6	281–301	295	287
Men	27	291.5	6.9	275–301	292	285

continued

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Appendix 4 continued

	N	*M*	*SD*	Range	*MDN*	10%
Germany						
edu. 5–8 yrs						
Women	31	294.2	5.5	284–301	296	287
Men	21	294.0	5.1	283–301	295	286
edu. 9–12 yrs						
Women	30	296.7	3.4	289–301	297	291
Men	23	297.7	3.2	288–301	299	295
edu. >12 yrs						
Women	28	298.5	1.9	295–301	299	295
Men	26	298.5	1.9	295–301	299	296

Appendix 5

DISTRIBUTION OF THE SCORES AT EACH TASK IN LEFT AND RIGHT CVA PATIENTS

		Left hemisphere CVA ($n = 56$)				Right hemisphere CVA ($n = 24$)			
Task	Max	*MDN*	*p*10	%0	%max	*MDN*	*p*10	%0	%max
C1	8	6	0	14	34	8	6	0	83
C2	2	2	0	16	82	2	2	0	100
C3	4	2	0	45	34	4	2	4	75
C4	6	6	6	0	95	6	5	0	87
C5	6	6	4	0	84	6	4	0	75
C6	6	6	4	2	71	6	3	0	67
C7	6	6	4	2	71	6	4	0	75
C8	6	6	3	4	79	6	4	0	75
C9	12	12	2	5	62	12	12	0	92
C10	12	6	0	32	23	12	8	0	79
C11	12	10	0	25	32	12	8	0	75
C12	12	6	0	29	20	12	10	0	75
C13	12	10	0	16	41	12	10	4	87
C14	12	9.5	0	21	34	12	8	0	71
C15	12	8	0	20	34	12	6	0	54
C16	8	8	0	12	57	8	8	0	92
C17	8	8	2	4	66	8	8	0	96
C18	16	16	14	0	75	16	14	0	71
C19	16	14	6	0	16	14	10	0	37
C20	16	10	0	12	23	16	10	0	79
C21	16	12	4	7	29	16	12	0	71
C22	16	12	4	5	25	12	4	4	17
C23	10	10	6	0	79	9	4	0	50
C24	10	10	5	0	57	9	4	0	50
C25	8	8	2	7	55	8	6	0	87
C26	4	2	0	32	34	4	2	4	83
C27	4	2	0	32	43	4	2	4	67
C28	7	4	0	18	11	6	4	4	37
C29	12	10	4	2	39	10	8	0	21
C30	10	8	4	2	46	10	6	0	67
C31	10	12	6	2	62	12	12	0	96

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