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Dyscalculia in the early stages of Alzheimer's disease

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Objective – To study mathematical deficits in the early stages of Alzheimer's disease (AD). *Methods* – Sixty-eight patients with mild AD and 242 normal controls (NC) received a standardized battery (EC 301-R) assessing number processing and calculation abilities. AD patients also received testing for language, memory, visuo-spatial and executive-attentional domains. *Results* – Sixty-four AD patients (94.1%) showed impaired performances on the EC 301-R. Mathematical deficits were evident both on calculation and number processing skills. Performance on the single tasks was related to attentional-executive resources and to impaired number representations. Heterogeneous patterns of preserved/impaired mathematical abilities were also observed in single cases. *Conclusion* – Dyscalculia is an early sign of AD. It should be included among the reliable clinical hallmarks for the diagnosis of AD. Identification of dyscalculic symptoms in these patients requires composite assessment procedure.

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Disorders of mathematical abilities in Alzheimer's disease (AD) have received little attention in the neuropsychological literature. Calculation disorders have been described as the first complaint in few case reports of patients with high calculation proficiency (1, 2). Conversely, only 2 group studies have addressed this topic. The study by Parlato et al. (3) examined 28 subjects suffering from mild AD. Patients were found significantly impaired both when performing the SSST – Serial Seven Subtraction Test, from the MMSE – Mini Mental State Examination (4) and a calculation task, the ST – Stamp Test, from the WAIS (5). In another study by Deloche et al. (6), 12 out of 17 patients (70.6%) suffering from mild AD showed impaired performances on a composite standardized battery, the EC 301 (7), which assessed calculation and number processing abilities.

The 2 group studies also investigated relationships between dyscalculia and disorders in other cognitive domains, namely language, memory, attentional and visuo-spatial skills. In both studies no significant correlation was reported between calculation and memory impairment. In the study by Parlato et al. (3) performance on the SSST was related to MMSE and language scores, while the ST performance was also related to attentional resources. In the study by Deloche et al. (6) performances on calculation and number processing tasks were again related to MMSE and language score. However, in multiple single case analysis, these latter authors noticed that, even in this small sample, it was possible to identify heterogeneous patterns of preserved/impaired abilities with respect to the cognitive areas under investigation, i.e., dissociated performance between language and calculation; and to different components of calculation and number processing system, i.e., number production vs number comprehension. It was thus suggested that ". . . larger groups of demented patients should be considered in order to better characterize the patterns of different calculation deficit subtypes" (6).

The present study addressed the clinical definition of mathematical disability in the early stages of AD by means of a standardized composite battery for assessing calculation and number processing skills. It, however, concerned a larger sample of unselected patients with mild AD than in the previous study. Furthermore, we also investigated relationships between mathematical disorders and deficits in other cognitive domains, visuo-spatial abilities and executive-attentional functions, which have not been considered in the previous study.

Table 1. General and demographic variables of the AD and NC groups

AD				
French speaking: *n*: 45 (14 men; 31 women)				
Italian speaking: *n*: 23 (11 men; 12 women)				
	French		Italians	
	Mean	SD	Mean	SD
Age (years)	71.2	5.2	62.6	7.1
Schooling (years)	11.6	3.3	10.4	2.2
Duration of illness (months)	28.3	20.8	19.9	7.3
MMSE score	20.8	2.4	21.3	2.5
NC				
French speaking: *n*: 89 (36 men; 53 women)				
Italian speaking: *n*: 153 (76 men; 77 women)				
	French		Italians	
	Mean	SD	Mean	SD
Age (years)	66.3	6.4	60.5	5.3
Schooling (years)	13.2	3.1	11.5	3.7

Methods

Subjects

Sixty-eight patients, suffering from Dementia of the Alzheimer's type (AD) according to DSM-IV criteria (8) were involved in the study. Forty-five patients were French speaking subjects, the remaining were Italian speaking. Inclusion criteria were age, from 45 to 80 years; schooling, at least 8 years; MMSE score equal or greater than 18; Hachinski ischemic score (9) less than 4. All patients underwent extensive evaluation including neurological examination, standard EEG, brain CT-scan or MRI and laboratory screening to rule out other causes of dementia. Exclusion criteria were the evidence of significant neurological and/or psychiatric disorders and the presence of focal abnormalities in neuroimaging studies.

Demographic variables are summarized in Table 1.

A group of 242 normal subjects (153 Italians and 89 French), matched with patients for the demographic variables, served as the control (NC).

Neuropsychological evaluation

The neuropsychological evaluation included tests tapping four cognitive domains for which standardized norms were available both for French and Italian subjects. Language examination included the Token test, naming, and tasks of verbal fluency by letters and by semantic categories. The Language composite score averaged z-transformations of corrected scores on these tests. Memory abilities were evaluated by means of 3 tests: paired associated learning, logical memory and digit span forward from the Wechsler Memory Scale (10). The total Memory score was derived from these corrected subscores. Testing for visuo-spatial abilities included tasks for constructive apraxia, the Raven's Coloured Progressive Matrices 1947 test and the Corsi block test, while evaluation of Executive-attentional skills included the Trail making form B, the digit-symbol substitution from the WAIS, the graphic tapping test and the backward digit span.

The MMSE was also administered to grade dementia severity. To avoid bias in calculation performance, the adopted version of the MMSE did not include the SSST, but the "world" backward spelling test (3).

To assess mathematical skills all patients were given the French or Italian revised version of the original EC 301 composite battery (7), which explores both calculation and number processing abilities. In the revised version, EC 301-R, there are fewer tasks (from 31 to 13). This made it possible to assess mathematical abilities in less time (about 30 min) and reduce fatigue.

The number processing system, in EC 301-R, is assessed by 6 tests (i.e., placing numbers on an analogue number line; magnitude comparisons in oral and orthographic number form; reading aloud and writing numbers from dictation in digit form; transcoding a number from digit to orthographic written form). These tasks allow number comprehension and production to be explored in the 3 numerical notational systems (digits, oral and orthographic number forms). Calculation skills are assessed by 3 tests exploring mental calculation, performing written calculation and complex problem solving following Luria (11). In addition to these tasks that assessed different components of the calculation and number processing model proposed by McCloskey et al. (12, 13), other numerical skills were evaluated. Context-related and perceptual numerical judgements were assessed by 2 separate tests. Enumeration of dot patterns and counting backwards were also included. All these tasks have been described elswhere (7) and will not be further illustrated.

Following this structure, 4 principal arithmetical domains were identified inside the EC 301-R for a clinical description. The Number Production dimension included the 3 tasks which required transcoding numbers from one notational system to another. Number Comprehension included the 3

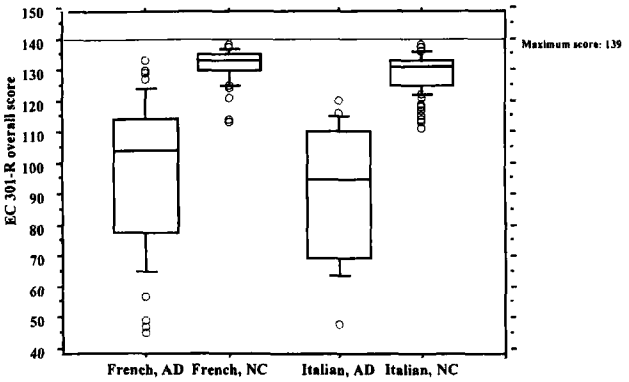

Fig. 1. EC 301-R overall score of AD and NC for the French and Italian groups.

tasks requiring access to abstract numerical representations. Numerical Judgements included tasks of perceptual quantity and contextual magnitude judgement. Calculation and Problem solving included written and oral calculation tasks plus the problem solving task from Luria (11). Enumeration of dot patterns and counting backwards tasks were eliminated because they had demonstrated ceiling effect (and were thus not sensitive to the presence of calculation and number processing disorders) or when they were highly correlated to another task that was less time consuming. For each arithmetical dimension a cumulative score was obtained by summing performance on all items of the tasks included.

The effects of demographic variables on the overall EC 301-R score and those related to the 4 arithmetical domains were checked by separate multiple regression analyses on data from normal controls. Each score was considered a dependent variable while nation, gender, age and schooling were all independent ones. A linear regression model was identified that could be used to adjust the original score for the sensitive independent variable(s). Terms were included in the model only when the significance reached $P<0.0125$ level, after Bonferroni correction for the 4 independent variables. Due to the asymmetric distribution of adjusted scores in NC, parametric measures were avoided for single case analysis, and outer and inner tolerance limits have been described as 95% confidence interval on the 10th centile (14, 15).

Following the same procedure, cut-off values for discriminating normal from pathological performance were also obtained for each subtest of the EC 301-R battery.

Computation was supported by the statistical package StatView 4.5 (Abacus Concepts Inc., Berkeley, CA) running a Macintosh personal computer.

Results

A) Whole group trends

Comparison on the EC 301-R overall score between experimental and control groups was performed by two-way ANOVA (group × nationality) on the raw data. This showed a significant effect of group ($F=447.0$; $P<0.0001$) and of nationality ($F=6.87$; $P<0.01$) with no interaction ($F=1.41$; NS). NC performed better than AD patients, and the French did better than the Italian subjects. Fig. 1 summarizes EC 301-R overall score of both AD patients and NC, respectively for the French and Italian groups.

When the EC 301-R overall scores were taken into account all Italian AD patients and 41 out of the 45 French (94.1%) fell below the cut-off value for impaired performance ($P<0.10$). A further comparison between AD and NC groups concerned the 4 arithmetical domains which had been previously identified, see above. To this purpose, cumulative scores on all items included in each domain were transformed as percentage of the maximum score and analyzed by separate Mann–Whitney *U*-test, after Bonferroni correction. Within group comparison was checked by means of Friedman's ANOVA and post-hoc Nemenyi test.

AD patients performed lower than NC on all the 4 arithmetical domains tapped by the EC 301-R ($P<0.001$). Performance of NC ranged from 92% on Calculation and Problem solving tasks to 97% on Number Production. A significant difference was found between all the 4 domains ($P<0.001$, *post-hoc* Nemenyi test). In the case of AD patients, performance ranged from 54% of accuracy on Calculation and Problem solving to 74% on Number Production. Furthermore, their mean score on Calculation and Problem solving tasks was lower than those on the other 3 domains ($P<0.01$). No other differences were found.

The last finding could indicate that Calculation and Problem solving dimension was more sensitive to AD than those involving other mathematical abilities. However, the percentage of patients who scored under the cut-off value on Calculation and Problem solving, 77.9%, was no different from those observed for Number Production (72%), Numerical Judgements (64.7%) and Number Comprehension (80.8%), see Table 2.

Correlations between the EC 301-R overall score, performance on the 4 arithmetical domains and scores on the 4 extra-calculation areas or MMSE were evaluated on standardized data from the experimental group. These scores were z-transformed and entered a partial correlation matrix.

Table 2. Performances of AD patients on the 4 arithmetical domains

	Number comprehension	Number production	Calculation and problem solving	Numerical judgement
Mean score	30.07	27.10	19.22	13.35
SD	7.59	7.63	8.59	3.32
AD patients below the cut off level ($P<0.10$)	55/68	49/68	53/68	44/68
Sensitivity	80.8%	72%	77.9%	64.7%

The overall EC 301-R score was not related to dementia severity, nor to performances on the extra-calculation tests, but to those tapping Executive-attentional functions ($r=0.588$; $P<0.0001$).

Significant positive correlations were also found between the Executive-attentional scores and scores on the 4 arithmetical domains except Number Comprehension, see Table 3. However, an effect of reduced attentional skills on Number Comprehension performances could be due to reduced memory abilities fitting in the working memory model (16). This effect could have been masked by the composite structure of the Executive-attentional score, see Methods. To examine this aspect, correlations between scores on the 3 comprehension tests and the forward and backward digit span were computed. None approached significance.

Other positive correlations concerned the 4 calculation and number processing measures with the only exception of the comparison between Numerical Judgements and Number Comprehension.

In order to characterize factor(s) affecting performance of AD patients, scores on the 11 out of the 13 EC 301-R subtests belonging to the 4 main arithmetical domains were z-transformed and entered a Principal Component Analysis. The analysis generated 2 Factors having an initial eigenvalue of 4.32 and 1.17 respectively which included all the variables but the mental calculation task. The two Factors explained about 50% of the variance. The resulting two component solution was then rotated using the Varimax procedure and this component structure is shown in Table 4.

The reference structure matrix showed that Factor 1 was related to all Number Comprehension subtests plus the Luria's problem solving task. Factor 2 was related to all Number Production subtests, to those exploring Numerical Judgements and those for written calculation.

B) Single case analysis

A single case analysis was then made to identify patterns of impaired/preserved abilities which could be abnormal compared to group trends.

1) Relationships between dyscalculia and extra-calculation areas – As far as correlation between the EC 301-R scores and the Executive-attentional deficit is concerned, dissociation between mathematical skills and Executive-attentional performance was observed. Patient 9, a 74-year-old French woman, with 14 years of education,

Table 3. Arithmetical domains and extracalculation areas partial correlation matrix

	Number comprehension	Number production	Calculation and problem solving	Numerical judgement	EC 301-R overall score
MMSE	0.055	0.345	0.316	0.179	0.263
Language	0.355	0.380	0.393	0.297	0.418
Memory	0.226	0.428	0.280	0.163	0.339
Visuo-spatial	0.242	0.152	0.233	0.323	0.357
Executive attentional	0.447	0.517**	0.476**	0.455*	0.588***
Number comprehension		0.453*	0.599***	0.295	0.736***
Number production			0.566***	0.472*	0.811***
Calculation and problem solving				0.480**	0.808***
Numerical judgement					0.678***

*$P<0.002$; **$P<0.001$; ***$P<0.0001$.

Table 4. Factor analysis (AD group). Values greater than 0.50 are underlined

	Magnitude	Variance
Eigenvalues		
Factor 1	4.327	0.393
Factor 2	1.166	0.106
Factor 3	0.979	0.089
Factor 4	0.876	0.080
Factor 5	0.762	0.069
	Rotated factors loadings after Varimax	
	Factor 1	Factor 2
Digit comprehension	0.775	−0.034
Oral comprehension	0.568	0.065
Alphabetic comprehension	0.653	0.271
Digit production	0.415	0.516
Oral production	0.132	0.611
Alphabetic production	0.340	0.522
Mental calculation	0.459	0.438
Written calculation	0.435	0.534
Luria's problem solving	0.676	0.000
Numerical judgements (perc.)	−0.025	0.603
Numerical judgements (cogn.)	−0.092	0.703

Bartlett's Chi Square: 225.506; P value < 0.0001.

showed quite normal calculation abilities (EC 301-R total score = 128), but significantly reduced Executive-attentional skills (below the 5th centile). This subject scored 24 on MMSE and was seen impaired (below the 5th centile) when assessed on language tasks. The reverse was observed in 2 Italian subjects (cases 46 and 49), who showed impaired mathematical skills (EC 301-R total scores 96 and 117, which respectively fell below the 5th and the 10th centile) but preserved Executive-attentional skills (in both cases at the 50th centile).

2) Selective disruption and selective preservation of main arithmetical domains – To summarize data on individual patterns, single patient performance was considered impaired or preserved for each arithmetical domain compared to 95% tolerance limits (outer or inner) on the 10th centile (14, 15).

Twenty-seven patients (39.7%) showed impaired performance on all the 4 arithmetical domains. Conversely, scores of 1 patient (case 1) fell within the limits of normal performance on all tests tapping mathematical skills. The other 3 patients with normal overall EC 301-R score showed marginal performances on Number Comprehension (case 9), marginal performances on Number Production and impaired performance on Numerical Judgement tasks (case 23), and selective impairment on Numerical Judgement (case 32).

Unimpaired performance only on 1 arithmetical domain was found in 10 patients: 2 on Number Production subtests (case 31 and 39), 1 on Calculation and Problem solving (case 35) and 7 on Numerical Judgements (cases 5, 7, 24, 28, 56, 59, 67). For 7 others, this pattern was less clear since marginal performance on another domain was found. Among them we also found a subject with spared Number Comprehension alone, case 54.

Some of these patients deserve further description. Selective preservation of Calculation and Problem solving skills was observed in patient 35. She was a 70-year-old French speaking woman with 8 years of education, scoring 23 on MMSE. She showed preserved Language and Visuospatial reasoning abilities, but defective performance on Memory and Executive-attentional tests. Her Number Comprehension skills were unimpaired only on oral presentation, and she correctly produced numbers only in arabic form. Performance on tests tapping mental calculation was marginal, but she performed well, although very slowly, when executing written calculation and Luria's problem solving task.

The 2 patients showing unimpaired Number Production, cases 31 and 39, were a 65-year-old woman and a 68-year-old man. Both were well educated subjects with 13 years of schooling. Case 31, scoring 22 on MMSE, had poor Language and Memory skills, marginal Visuo-spatial score and good attentional resources. She showed unimpaired performance on the three Number Production tasks, on the task tapping oral calculation and in number comprehension on oral presentation. The other subject, case 39, also scoring 22 on the MMSE, showed poor performance on all extra-calculation domains. He performed poor on all calculation tasks except the three concerning Number Production.

Three patients, on the other hand, did show selective impairment on tests tapping Number Comprehension (case 14), Number Production (case 17) and Numerical Judgements (case 32). Case 14 was a 64-year-old French speaking woman with 8 years of education. She scored 22 on MMSE and had impaired language and memory skills. Her total EC 301-R score fell below the 10th centile. She was competent on all subtests of the EC-301 R battery except in number comprehension on oral and alphabetical presentation where performance dropped below the 10th centile. Case 17 was a 62-year-old French speaking woman with 8 years of education. She scored 23 on MMSE and exhibited severe memory and expressive language deficit. Unimpaired performance was found on all EC-301-R subtests except those for number production in

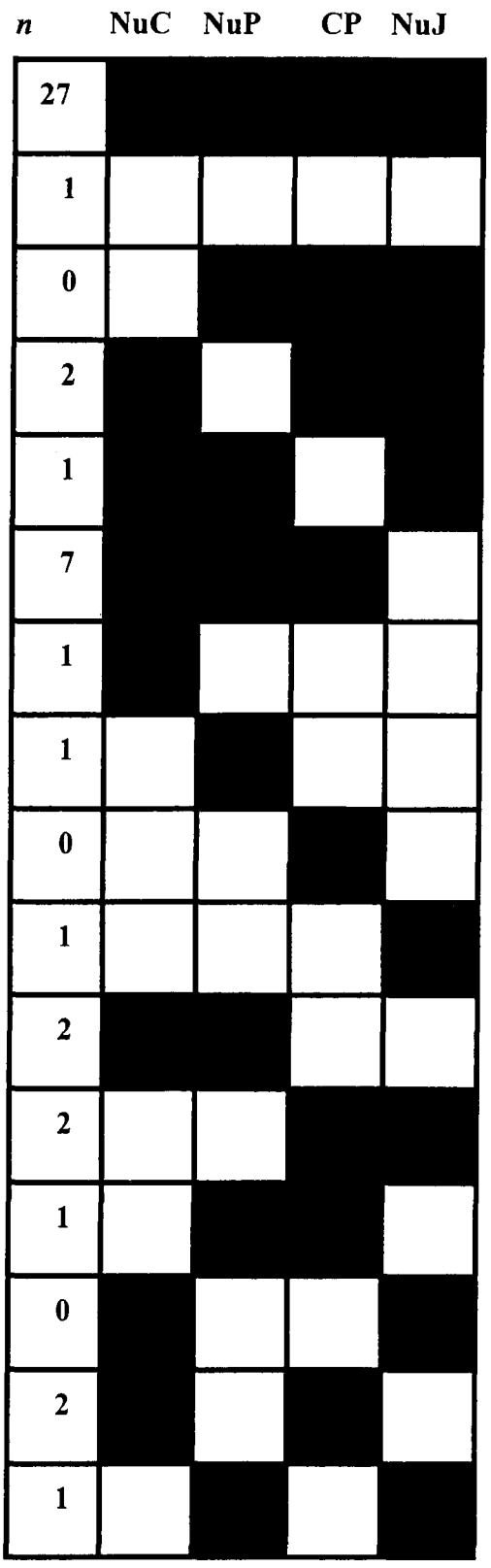

Fig. 2. Patterns of preserved (white squares) and impaired (grey squares) performances on the 4 arithmetical domains. *n*: number of AD patients exhibiting the pattern; NuC: Number comprehension; NuP: Number production; CP: Calculation and problem solving; NuJ: Numerical judgements. Patients with borderline performances are not included in the schema.

alphabetic and digit code and on Luria's problem solving task.

Four other patients showed the pattern of selective impairment in only 1 domain although marginal performance in another was found. Only 1 patient, case 18, showed deficit in Calculation and Problem solving as the only significant impairment, but he also exhibited marginal performance in Number Production. The last feature was due only to his poor performance in producing numbers in orthographic form. This patient was a 62-year-old man, scoring 24 on the MMSE, with preserved language abilities, but very poor memory, attentional and visuospatial skills. Patient 45 was a 76-year-old woman scoring 21 on the MMSE. She showed unimpaired verbal and visuospatial abilities but reduced attentional and memory skills. A significant impairment in Number Comprehension except in the arabic form characterized her performance, but she scored almost at normal level on all other subtests of the EC 301-R.

Other patterns of impaired/preserved abilities are also shown in Fig. 2. These patterns, however, will not be described further.

3) Selective preservation and selective impairment on single components of calculation and number processing systems – The principal component analysis indicated that the 2 Factors resulted in a strong association of performances in number production and number comprehension respectively, regardless to the stimulus or response code. However, there was a number of instances where the 2 correlations were not in agreement, namely in patients who showed selective impairment or selective preservation of number production and comprehension in only 1 numerical notational system. Selective preservation of number comprehension in only 1 code was observed in 11 patients. Conversely, selective impairment in number comprehension in only 1 code was observed in 12 patients. A similar finding concerned number production skills, but in this case the selective preservation of number oral production was the most consistent pattern (17 cases).

As far as the calculation subsystems are concerned, selective preservation of mental or written calculation could also be observed. Six patients exhibited unimpaired mental calulation skills but defective written calculation, while the reverse pattern was found in 24 subjects.

Discussion

Dyscalculia is an early sign of AD. This has been suggested by the pilot studies by Parlato et al. (3)

and Deloche et al. (6). It receives strong epidemiological support from the present finding that about 94% of patients suffering from mild AD showed impaired calculation and number processing skills on standardized assessment. Dyscalculia may cause significant impairment in daily activities (17). Thus we agree with the issues raised by both Parlato et al. (3) and Deloche et al. (6) that even widely accepted criteria (8, 18) for the diagnosis of AD make no reference to arithmetical disability in these patients.

It is noteworthy that the prevalence of arithmetical disability found here was more important than in the Deloche et al. (6) study (94.1 versus 70.6%). In the last case, however, there was an additional criterion to include patients with mild AD in the study, i.e., preserved visuo-perceptive skills. This probably excluded a percentage of patients with relevant arithmetical deficit.

Here we used the reduced form of a standardized battery, the EC 301 (7). Such a reduced form still includes a variety of tasks which deal with basic arithmetical skills and explore number processing in the 3 main notational systems. This structure allowed us to separately evaluate AD patients performance on 4 main arithmetical domains and demonstrate significant impairment in all of them. We found no differences among these areas of arithmetical proficiency in the percentage of AD patients who scored pathologically. These findings suggest that even early AD can affect all aspects of cognitive processing that allow arithmetical skills and complements previous findings on deficits in these patients on mental calculation (1–3) and number processing (6).

AD patient performance on the EC 301-R was not related to deficits in other cognitive domains, i.e., Language, Memory and Visuo-spatial abilities except the Executive-attentional. This was in disagreement with findings from the 2 previous group studies where significant correlations between dyscalculic symptoms and dementia severity (MMSE score), language and/or visuo-spatial deficits were found, see Introduction. However, the study by Parlato et al. (3) only concerned 2 mental calculation tasks. On the other hand, differences in testing procedure likely account for discrepancies with results by Deloche et al. (6). For instance, in their study, 4 out of 5 language tasks involved oral production as well as a large set of number processing tests. This could mask possible dissociation between language deficit and performance on arithmetical tasks since both symptoms could be simply related to the left hemisphere cortical involvement in AD subjects. Interestingly, Deloche et al. (6) stressed that even in their small sample, there was a case with noticeable dyscalculia with no language deficit. In our study the opposite was observed in case 9 (see earlier).

Still on the subject of Deloche's et al. (6) results, similar concerns might be raised about the correlation between MMSE score and performance on the EC 301 found by these authors. We found no such correlation. However, unlike Deloche's et al. (6) method, the MMSE in our study did not include the SSST subtest but the "world" backward spelling test. It should be noted that our findings do not lead us to conclude that calculation difficulties in AD are not related to dementia severity. They only support the view that dyscalculia in early AD may be independent from deficits shown in other cognitive domains and from results obtained by usual AD screening/grading methods such as the MMSE.

Our results indicate an important correlation between performance on the Executive-attentional tasks and the overall EC 301-R score. A comparable result, i.e., positive correlation between the Stamp Test and speed-attentional score, has been obtained by Parlato et al. (3) while Deloche et al. (6) have not addressed this aspect. Parlato et al. (3) stressed how performing mental calculation is dependent on attentional resources. In our study the Executive-attentional score was not only related to Calculation and Problem solving, but also to scores on Numerical Judgements and Number Production tasks. This pointed out the role of attentional resources not only in performing calculation, but also in accessing abstract mathematical knowledge and in producing numerical responses.

As for the correlation between performance on Numerical Judgement tasks and the Executive-attentional score, we must argue that recovering information from the semantic system to perform Numerical Judgements is allowed by component(s) of the Executive-attentional system. Another explanation, however, only points to the anatomical contiguity of cortical areas involved in executive tasks and those for performing Magnitude Judgements (19).

The principal component analysis indicated a common factor affecting performance on all the number comprehension tasks. This factor could not be interpreted in terms of reduced working memory resources (16) since they are unlikely involved in the digit comprehension task (placing a visually presented number on an analog scale). Nor could this factor be explained as attentional in nature since Number Comprehension score was the only one not related to the Executive-attentional. We argue that the other factor which impair calculation and number processing skills in AD

patients is deficit in accessing semantic representations of numbers (abstract numerical entities) or degraded representation itself. This interpretation is not contradicted by the finding that performance on Luria's problem solving task was also related to factor 1 in the principal component analysis. This task is obviously dependent on planning and working memory resources. However, it is likely dependent on preserved (access to) abstract numerical representations necessary to compute the correct response.

Taken together these findings indicate that at least 2 factors which underly dyscalculic symptoms in AD subjects pertain, on one hand, to degraded representation of numerical entities (or defective access to these representations) and, on the other hand, to attentional resources to compute correct numerical outputs. The relative extent of these 2 factors resulted in a variety of dyscalculic symptoms which account for most daily difficulties experienced by AD subjects in drafting cheques, performing simple calculations or comprehending price lists and counting small change. This, once again, points out the ecological validity of assessing dyscalculia for the diagnosis of AD (17).

We found, however, a third source of variety of dyscalculic symptoms. Single case analysis highlighted that in patients with mild AD it is possible to find patterns of preserved/impaired calculation and number processing skills which violated the whole group trends (6). For instance, in a few cases, dissociation between performance on mathematical tasks and Executive-attentional skills was observed and reduced performance as well as unimpaired performance on only one mathematical domain was found. Furthermore, we found dissociations between performance on number production and/or comprehension in the 3 main notational systems. These patterns shared analogies with previously described cases of acquired dyscalculia in patients with focal brain damage. This was true for patient 17 (see above), whose dyscalculic profile mimed those of patients described by Benson & Denckla (20) and by McCloskey et al. (12). These patients showed deficit in number production despite of preserved number comprehension abilities. Another patient, case 14, exhibited pathological performances on number comprehension in both oral and alphabetical codes, and normal performances on digit comprehension. Such a pattern has been described in the acquired dyscalculic patient HY, who showed chance-level performances on a task of number comparison in alphabetic code and almost error-free performances when stimuli were presented in digit form (12). Furthermore, patient 3 showed difficulties in processing numbers only in digital code. This shares analogies with performances of previously described patients K (12) and SF (21). The last patient, for instance, exibited 95% accuracy in reading numbers in orthographic code, but only 45% accuracy when stimuli were presented in digit form. A reverse pattern, in our sample, concerned patient 23, who showed a selective deficit in producing numbers in alphabetic code, in analogy with the patient described by Anderson et al. (22).

Finally, it is interesting to note that a few patients showed non-homogeneous performances on the tasks tapping, respectively, mental and written calculation. These findings are in agreement with data from acquired dyscalculia in focal brain damaged patients (23) and in dementia (2), which demonstrate the relative independence of arithmetic facts knowledge from calculation procedures.

Our assessment method could not deeply analyze dissociated performance in early AD subjects on calculation and number processing. However, heterogeneous patterns of dyscalculic symptoms found here support the view that even identification and clinical description of dyscalculia in patients with mild AD require assessment procedures based on the modular architecture approach.

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