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ARITHMETICAL ABILITIES IN ALZHEIMER DISEASE*

MONICA ROSSELLI[a,†], ALFREDO ARDILA[b], LILIA ARVIZU[c], TRACY KRETZMER[a], VIRGINIA STANDISH[a] and JASON LIEBERMANN[a]

[a]*Florida Atlantic University;* [b]*Miami Institute of Psychology;* [c]*Health South Rehabilitation Center*

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The purpose of this research was to analyze the calculation abilities in Alzheimer Disease (AD). Twenty right-handed patients meeting the DSM-IV (American Psychiatric Association, 1994) criteria for AD were studied. Age ranged from 64- to 88-year-old. A neuropsychological test battery including language, memory, constructional abilities, attention, mathematics, and abstraction tests was administered. In addition, the Mini-Mental State Exam (MMSE) (Folstein, Folstein, McHugh, 1975) was also administered. Mathematical subtests correlated higher than the MMSE with the scores in the different neuropsychological tests. Highest correlations of the mathematical subtests were observed with language repetition, non-verbal memory, and attention tasks. It is proposed that mathematical ability tests represent in AD an excellent predictor of general intellectual performance. It is further proposed that disturbances in arithmetical ability should be included as a diagnostic criteria for AD.

Keywords: Arithmetical abilities; Alzheimer Disease; MMSE; dementia

Calculation abilities represent an important aspect of cognition. To a significant extent, it reflects the ability to manipulate acquired knowledge (Mandell, Knoefel and Albert, 1994). Calculation deficits have been reported as an early sign of Alzheimer Disease (AD) (Grafman, Kampen, Rosemberg and Salazar, 1989; Deloche *et al.*, 1995; Parlato *et al.*, 1992).

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†Address for correspondence: Florida Atlantic University, College of Liberal Arts, Division of Science, Department of Psychology, 2912 College Ave, Davie, FL 33314-7714. e-mail: mrossell@fau.edu

Mental calculation impairments represent an important factor in predicting cognitive deficits in these patients (Roudier *et al.*, 1991).

The most frequently used clinical criteria for the diagnosis of AD (*e.g.*, NINCDS, McKhann *et al.*, 1984; DSM-IV, American Psychiatric Association, 1994) do not list the numerical ability defects as part of the accepted manifestations of dementia. Clinical criteria of dementia usually emphasize memory disturbances, language deficits, attention defects, and visuoperceptual disturbances. Very little research concerning the functions of the mathematical abilities in AD is found.

A substantial body of research has substantiated the neuropsychological deficits of AD (Cummings and Benson, 1992). AD patients with different cognitive profiles have been described (Fisher *et al.*, 1996). Very few studies, however, have included the assessment of mathematical abilities (Martener *et al.*, 1996; Deloche *et al.*, 1995) as a diagnostic criterion in AD.

Recently, studies have been published pointing out that calculation abilities represent a very significant defect in AD. Martener *et al.* (1996) found a significant correlation between arithmetic impairment and the degree of dementia. Deloche *et al.* (1995) reported that calculation and number processing scores correlated highly with the MMSE and language performance.

However, their case analysis indicated heterogeneous patterns of preserved/impaired abilities with regard to other cognitive areas. Heterogenous patterns of calculation deficits in brain damaged patients have been reported by different authors (Ardila and Rosselli, 1990; Boller and Grafman, 1985; Grafman, Passafiume, Faglioni and Boller, 1982; Rosselli and Ardila, 1989).

Calculating has been identified as a concept and goal formation cognitive skill (Mandell, Knefel and Albert, 1994). Very little research, however, has been done to explore the relationship between mathematical tests and other cognitive tests.

The aim of the present study was to investigate the correlations of two calculation tasks with other cognitive functions in AD patients.

METHOD

Subjects

Neuropsychological data from 20 right-handed patients meeting the *Diagnostic and Statistical Manual for Mental Disorders*, 4th edition (DSM-IV)

(American Psychiatric Association, 1994) criteria for AD were analyzed. All patients received general medical and neurological examinations, and were taken from the Behavioral Neurology unit of Jackson Memorial Hospital (Miami, Florida). No patient displayed focal motor or sensory findings on neurological exam. All patients underwent CT or MRI scanning failing to revel any significant focal abnormalities. Mean age was 75.7 years (SD = 6.4; range 64 – 88). Mean educational level was 13.0 years (SD = 4.2; range 3 – 18). Nine women and 11 men were included in this study.

Neuropsychological Testing

A neuropsychological battery was individually administered to each subject. The battery included the following neuropsychological tests:

1. Language
   - 1.1. Boston Naming Test (Kaplan, Goodglass, Weintraub, 1978).
   - 1.2. Reading comprehension from the Multilingual Aphasia Examination (MAE) (Benton and Hamsher, 1976).
   - 1.3. Sentence repetition from the MAE (Benton and Hamsher, 1976).
   - 1.4. Controlled word association (COWAS) subtest from the MAE (Benton and Hamsher, 1976).
   - 1.5. Semantic verbal fluency (animals) (Spreen and Strauss, 1991).
2. Memory
   - 2.1. Information from the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981).
   - 2.2. Logical Memory taken from the Wechsler Memory Scale-Revised (WMS-R) (Wechsler, 1986).
   - 2.3. Visual Reproduction subtest from the WMS-R (Wechsler, 1986).
3. Constructional
   - 3.1. Rey-Osterrieth Complex Figure (Osterrieth, 1944; Lezak, 1995).
   - 3.2. Block Design subtest from the WAIS-R (Wechsler, 1981).
4. Spatial
   - 4.1. Judgement of line orientation (Benton, Hamsher and Spreen, 1983).
5. Attention
   - 5.1. Trail Making Test, Forms A and B from the Halstead-Reitan Neuropsychological Battery (Reitan and Wolfson, 1985).

5.2. Digit Span from the WAIS-R (Wechsler, 1981).
5.3. Mental Control subtest from the WMS-R (Wechsler, 1986).

6. Mathematics

6.1. Arithmetic subtest of the WAIS-R (Wechsler, 1981).
6.2. Successive addition (1, 4, 7, ...) from the Mental Control subtest from the WMS-R (Wechsler, 1986). Number of errors was scored.

7. Abstraction

7.1. Similarities subtest from the WAIS-R (Wechsler, 1981).

8. General cognitive functioning

8.1. Mini-Mental State Exam (MMSE) (Folstein, Folstein and McHugh, 1975).

Testing was performed at the Division of Behavioral Neurology of the Jackson Memorial Hospital as a part of their general clinical examination.

Statistical Analysis

A correlation matrix was obtained within the test scores. MMSE and the two mathematical ability tests (Arithmetic subtest of the WAIS-R and Successive Additions from the Mental Control of the WMS-R) were analyzed.

RESULTS

Means and standard deviations in the different neuropsychological tests are presented in Table I. Reading Comprehension, Sentence Repetition, and Digit Span Forward were in average the best preserved test scores. Naming, memory and constructional abilities, mathematics, and abstraction test scores were notoriously abnormal. For most of the tests, standard deviations were high. Some heterogeneity of the sample can be assumed.

The MMSE, and the two arithmetical scores (WAIS-R and Successive additions) were correlated with the scores in the different neuropsychological tests (Tab. II). MMSE significantly correlated with the following ten test scores: MAE Sentence Repetition, WMS-R Logical Memory, WMS-R Visual Reproduction, WAIS-R Block Design, Judgement of Line Orientation, TMT Form A, Digit Span Forward, Digit Span Backwards, Total

TABLE I Means, and standard deviations, in the different neuropsychological tests. Maximum possible test scores are indicated

Test	*Maximum*	*Mean*	*SD*
LANGUAGE			
Boston Naming Test	60	27.3	15.8
Reading Comprehension	21	15.1	4.4
Sentence Repetition	17	8.1	3.1
COWAS	*n/a*	20.6	11.6
Semantic Fluency	*n/a*	7.3	3.9
MEMORY			
Information	18	6.4	3.1
Logical Memory – immediate	25	3.8	4.8
Visual Reproduction – immediate	41	8.2	6.2
CONSTRUCTIONAL			
Rey-Osterrieth Complex Figure	36	14.1	11.2
Block Design	19	5.4	3.2
SPATIAL			
Judgement of Line Orientation	30	5.8	4.6
ATTENTION			
Trial A (time)	*n/a*	143.0	86.0
Trial B (time)	*n/a*	284.8	94.3
Digit Span Forward	12	5.2	0.9
Digit Span Backwards	12	3.1	1.3
Total Digits	24	7.5	2.5
MATHEMATICS			
Arithmetic	19	5.8	1.7
Mental additions	14	5.3	5.7
ABSTRACTION			
Similarities	19	5.8	3.3
GENERAL COGNITIVE FUNCTIONING			
MMSE	30	16.9	4.4

Digits, and WAIS-R Arithmetic. Highest correlation were observed with the MAE Sentence Repetition subtests ($r = 0.768$; $p < .001$) and the WAIS-R Arithmetic subtest ($r = 0.715$; $p < .001$).

The Arithmetic subtests of the WAIS-R significantly correlated with the following 11 test scores: MAE Sentence Repetition, WAIS-R Information, WMS-R Visual Reproduction, WAIS-R Block Design, Judgement of Line Orientation, TMT Form A, Digit Span Forward, Digit Span Backwards, Total Digits, and WMS-R Mental Addition. Correlation with MMSE was 0.715 ($p < .001$).

The Successive Addition subtest of the WMS-R significantly correlated with the following 13 test scores: MAE Sentence Repetition subtest, MAE

TABLE II Correlations among the different neuropsychological subtests and the Mmse and arithmetic subtests in the dementia group ($n = 20$)

Test	*MMSE*		*Arithmetic*		*Additions*	
	r	*p*	*r*	*p*	*r*	*p*
LANGUAGE						
Boston Naming Test	0.361	.093	0.413	.063	0.150	.297
Reading Comprehension	0.273	.153	0.009	.487	0.368	.080
Sentence Repetition	0.768	.001	0.600	.005	0.731	.001
COWAS	0.287	.117	0.113	.328	0.451	.023
Semantic Fluency	0.280	.139	0.342	.139	0.462	.031
MEMORY						
Information	0.351	.070	0.486	.021	0.395	.042
Logical Memory	0.423	.040	0.393	.053	0.149	.277
Visual Reproduction	0.751	.002	0.727	.002	0.546	.022
CONSTRUCTIONAL						
Rey-Osterrieth Figure	0.354	.107	0.279	.167	0.307	.133
Block Design	0.623	.003	0.431	.042	0.405	.043
ATTENTION						
Trail A	0.805	.001	−0.566	.017	−0.557	.015
Trail B	0.492	.089	−0.315	.204	−0.148	.341
Digit Span Forward	0.431	.037	0.569	.009	0.456	.029
Digit Span Backwards	0.558	.008	0.563	.009	0.477	.023
Total Digits	0.548	.009	0.580	.007	0.585	.001
MATHEMATICS						
Arithmetic	0.715	.001			0.520	.013

COWAS subtest, Semantic Fluency, WAIS-R Information subtest, WMS-R Visual Reproduction subtest, WAIS-R Block Design, Judgement of Line Orientation, TMT Form A, Digit Span Forward, Digit Span Backwards, Total Digits, Arithmetic, and MMSE. Highest correlation was observed with the MMSE (0.751; $p < .001$).

DISCUSSION

Our results support the hypothesis that a significant association exists between arithmetical impairments and the severity of dementia (Deloche *et al.*, 1995; Martener *et al.*, 1996). A significant correlation between calculation abilities and performance in different cognitive areas, including language, memory, constructional abilities, spatial skills, and attention, was found. Calculation abilities in this research were assessed using a problem solving test (Arithmetic subtest of the WAIS-R) and an arithmetic mental task (Successive Additions by 3's). Both tests presented high

correlations (0.715 and 0.751 respectively; $p < .001$) with the MMSE. These very robust correlations with the MMSE may suggest that arithmetical abilities represent good predictors of general cognitive performance in AD.

Some significant limitations, however, to this research study should be mentioned: (1) The sample was small and heterogenous, and (2) both mathematical tests are of verbal nature and encompass more cognitive capacities than pure numerical abilities.

Deloche *et al.* (1995) found in mild AD patients a correlation of 0.74 between total calculation and number processing scores and the MMSE. In our sample the two arithmetic test scores presented significant correlations with more neuropsychological test scores than the MMSE, as shown in Table II. Besides, correlations between arithmetical abilities and neuropsychological test performance were in general higher than correlations between the MMSE and neuropsychological test performance. Arithmetical ability tests may in consequence be considered to be even better predictors of general cognitive performance than the MMSE.

Deloche *et al.* (1995) found that patients with calculation and number processing deficits also showed impaired language performance. In our sample, AD patients who performed significantly lower on arithmetic tests also did poorly on attention tests, sentence repetition, semantic verbal fluency, information, visual reproduction, block design, and line orientation tests. It is noteworthy, repetition is one of the language skills that is well preserved in AD patients and in consequence, repetition impairments are considered significantly abnormal (Cummings and Benson, 1992; Ardila and Benson, 1996). Repetition of sentences involves preserved verbal memory span.

Deloche *et al.* (1995) report a lack of relationship between mathematical abilities and memory tests. In our sample, there was a significant relationship between mathematical scores and short-term memory such as visual reproduction and immediate memory measured with the digit span subtest. Short-term visual memory (Visual Reproduction subtest from the WMS-R) had a stronger correlation than short-term memory (Logical Memory from the WMS-R) with arithmetical ability tests and MMSE.

In summary, arithmetic ability tests seem to be excellent predictors of general cognitive performance. It is proposed that arithmetical ability disturbances should be included as an additional criterion of AD. Further research is required to pinpoint the impariments in calculation abilities associated with AD. The description of the performance of AD patients in calculation tasks, and the analysis of the pattern of errors in different AD stages, may contribute to a better understanding of dementia.

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