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FACTOR STRUCTURE OF NONVERBAL COGNITION

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In order to define the factor structure of nonverbal cognitive processes, 156 twenty to sixty year-old participants were selected in Medellin (Colombia). A neuropsychological test battery for assessing different nonverbal cognitive domains (attention, memory, visuoperceptual and visuoconstructive abilities, executive functions, praxis abilities, and written calculation abilities) was administered. Initially, independent factor analyses were carried out for each domain. Three attention factors (Sustained Attention, Divided Attention, and Processing Speed, 73.1% of the variance); two memory factors (Categorical and Non-Categorical Memory, 59.7% of the variance); two visuoperceptual and visuoconstructive factors (Sequential and Simultaneous, 54.0% of the variance); and two executive function factors (Categorization and Trial/Error, 82.0% of the variance) were found. Further, several sequential factor analyses using Varimax orthogonal rotations for noncorrelated variables were performed. The 32 test variables were included, but progressively some variables were removed. This procedure finally selected 13 variables corresponding to five factors accounting for 72.6% of variance. Factor 1 was an Executive Function factor (30% of variance). Factor 2 corresponded to a Sequential–Constructional factor (14.7%). Factor 3 represented a Processing Speed factor and accounted for 10.6% of the variance. Factor 4 was Visuoperceptual factor (9.5% of the variance). Finally, Factor 5 (7.8% of the variance) was a Nonverbal Memory factor. It was concluded that several, different cognitive dimensions are included in nonverbal cognition.

Keywords: Factor analysis; nonverbal cognition; neuropsychological testing; right hemisphere

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Factor analysis has been used as a statistical strategy to analyze the correlational structure of neuropsychological test batteries (*e.g.*, Ardila, Rosselli and Bateman, 1994; Ardila, Galeano and Rosselli, 1998; Ostrosky, Ardila and Rosselli, 1999; Ponton, Satz and Herrera, 1994). Interpreting factorial analysis results, however, has been controversial. Even when using the very same tests, factor structure may be different (Swiercinsky and Hallenbeck, 1975; Wagman, Heinrichs and Carpenter, 1987; Bornstein, 1983). Thus, to set a stable factor structure of cognitive processes has been elusive. Furthermore, some specific neuropsychological tests, such as the Wisconsin Card Sorting Test (Goldman *et al.*, 1996) and the Stroop Neurological Screening Test (Goldberg, 1988) can result in rather specific factors. Evidently, factor analysis presents a limited utility in such cases.

Multiple clinical observations, however, support the existence of different components not only in cognitive activity in general, but also in specific domains. These components become evident in simple and double dissociations between specific cognitive operations (Della Sala and Logie, 1993; McCarthy and Warrington, 1990). It has been reported, for example, that a patient can present a restricted defect in only one single variable in a neuropsychological test, whereas other variables are normal. Jones-Gotman and Milner (1977) observed a patient with right frontal pathology, presenting a specific defect in design fluency, and high scores in other visuospatial, visuomotor and verbal tests. Specific defects in some test scores have been reported by different authors associated with focal brain patholgoy (*e.g.*, Ardila and Rosselli, 1994; Hecaen and Ruel, 1981; Pineda, 1995; Warrington and Shallice, 1984). Factor analysis represents a potentially useful mathematical instrument in the component analysis of cognitive processes.

The ideal situation in a factor analytic study would be to find out those specific cognitive test variables holding a zero correlation with the variables measuring other different cognitive factors, and only correlated with those variables measuring the very same cognitive factor. However, this is impossible and every test variable is simultaneously measuring more than one domain, and saturated by more than one factor. As a matter of fact, neuropsychological measures were not developed departing from previous structural analyses, but from intuitive clinical observations. A test directed to measure memory, for instance, is also evaluating attention, language, executive function, *etc.*, depending upon the conditions of the test. Differences in factor structure of neuropsychological tests depend upon the characteristics of the instruments, the conditions used in testing, and the selected statistical criteria (Ardila, 1995; Brauer-Boone, Ponton, Grosuch, Gonzalez and Miller, 1998; Dillon and Goldstein, 1984; Greve, Brooks, Crouch, William and Rice, 1998; Gorsuch, 1983). Factor structure may be different if we include normal or abnormal subjects (Kopelman, 1991; Della Sala, Gray, Spinnler and Trivelly, 1998); if several instruments are used to measure just a single domain (Brauer *et al.*, 1998); and if normal adults (Ardila *et al.*, 1998) or abnormal children (Pineda *et al.*, 1998; Pineda, Ardila and Rosselli, 1999) are included. This means, that not only the conditions of the tests and testing are significant, but also the target population.

The purpose of this research was to analyze the factor structure of nonverbal neuropsychological battery in a normal general population sample and to test a multidimensional cognitive model for visual and motor-guided functions. An attempt was made to develop a test battery containing the minimal linguistic components. From the clinical point of view, such a test battery can be potentially useful in the assessment of aphasic patients. Most factor analytic studies have included linguistic processes in a significant proportion. The component structure and the syndrome classification of nonverbal processes remains an only partially settled question in neuropsychology (Benton and Tranel, 1993; De Renzi, 1982; Hécaen, 1962; Newcombe and Ratclliff, 1989).

METHOD

Subjects

One hundred fifty-six 19 to 60 year-old normal Colombian subjects (75 males, 81 females) living in Medellin (population around 2,000,000 inhabitants) were included in this study. All subjects were native Spanish-speakers. Participants were randomly selected from an official list of workers registered in the Occupational Department of the Social Security Institute of Antioquia (Medellín). At the time of the study all subjects were healthy and actively working at middle and large sized industries in Medellin. Subjects with antecedents of any neurological or psychiatric disorders were excluded from the sample. Table I shows the demographic characteristics of the participants. Three age groups (19–35, 36–50 and 51–60 year-old) and three academic achievement groups (defined by years of education: 1–9, 10–15, more than 15 years of education) were distinguished. Because the sample was selected from the factories and companies with more than 100 employees, and these organizations contract mainly qualified workers, only 10 (6.4%) of the participants had 5 or less years of education, only one (0.6%) had 1 year, and no illiterates were found. The mean years of education in group 1 (1–9) was 6.4 ± 2.4, in group 2 (10–15) it was 12.8 ± 1.5, and in group 3 (16–22) it was 17.1 ± 1.4. The sample was also stratified into two socioeconomic status (low and high) groups. The official city criteria were used to determine the socioeconomic status (SES) of the subjects. Medellin has been divided by the City Administration Board into six socioeconomic areas, ranging from Level 1 (lowest) to Level 6 (highest). This division is taken into account for tax collection and city service payments. People living in Level 1 areas are usually unqualified factory workers, domestic workers, and the like, who earn the minimal wage. People living in Level 6 areas are high-income professionals,

TABLE I Characteristics of the sample ($N = 156$)

Variable	*Frequency*	*Percentage*
Age		
19–35 years	67	42.9
36–50 years	77	49.4
51–60 years	12	7.7
Gender		
Male	75	48.0
Female	81	52.0
Schooling (grades)		
0–9	17	10.9
10–15	82	52.6
> 15	57	36.5
Socioeconomic status		
Low	109	69.9
High	47	30.1

industry owners, and the like. Participants included in our sample were divided into two SES groups: Low (city levels 1, 2 and 3 according to the City Administration Board), and high (city Levels 4, 5 and 6).

Neuropsychological Testing

A neuropsychological test battery, specially designed for this study, was individually administered. This battery was developed bearing in mind its potential applicability in aphasic subjects. Testing was performed in two sessions, each one lasting about 45–60 minutes. Graduate neuropsychology students under the supervision of a professor administered the tests.

The following domains and tests were included:

1. Attention
   - 1.1. Icon Cancellation Test.
   - 1.2. Square Cancellation Test.
2. Memory
   - 2.1. Nonverbal Selective Reminding (NSVR) (Breier *et al.*, 1996).
   - 2.2. Figure Memory Test (FMT).
   - 2.3. Semantic Cued Recall Memory (SCRM) (Pineda and Ardila, 1991).
3. Visuospatial and Visuoconstructive Abilities
   - 3.1. Motor Free Visual Perception (MVPT) (Coralusso and Hammill, 1980).
   - 3.2. Overlapping Figures Test (Poppelreuter, 1917; Ghent, 1956).
   - 3.3. To Match Faces (Peña-Casanova, 1990).
   - 3.4. Block Design taken from the WAIS-Spanish version (Wechsler, 1988).
   - 3.5. Picture Arrangement taken from the WAIS-Spanish version (Wechsler, 1988).
   - 3.6. Drawing–Command (Goodglass and Kaplan, 1986).
   - 3.7. Drawing–Copying.
4. Executive Function
   - 4.1. Wisconsin Card Sorting Test (Heaton, 1981).

5. Praxis
   5.1. Ideomotor Praxis.
6. Calculation Abilities
   6.1. Written Calculation (Ardila and Ostrosky, 1995)

These tests are explained in the Appendix. Thirty-two test scores were analyzed.

Statistical Analyses

The following statistical analyses were carried out: (1) Mean, ranges and standard deviations were calculated for all the variables in the different groups. (2) Tests were grouped in four major domains: attention, memory, visuoperceptual and visuoconstructive, and executive function. In this initial analysis Praxis Ability and Calculation Ability tests were not included. Exploratory factor analyses were carried out in each domain using oblique rotations. A factor was consider stable if it fulfilled the following criteria: (a) at least two variables (test scores) with correlations above .40 were included in this factor; (b) these variables were not shared with other factors; and (c) its eigenvalue was over 1.00 (Afifi and Clark, 1990). Nine stable factors were found. (3) A logarithmic transformation of the variables was carried out when there was a positive or negative skewness equal or over .70 with the purpose to correct the distribution. (4) Several sequential factor analyses using Varimax orthogonal rotations for noncorrelated variables were performed. Initially, the 32 test variables were included, but progressively some variables were removed. Nonstable factors and variables loading factors in an inconsistent way were deleted. This procedure finally selected 13 variables. (5) A confirmatory factor analysis was carried out. The method of Maximum Likelihood was used to find the best factor structure when using an orthogonal Varimax rotation (Afifi and Clark, 1990; Dillon and Goldstein, 1984; Long, 1983). Five factors accounting for 72.6% of the variance were found.

RESULTS

Table II presents the general results in the neuropsychological test battery. A significant dispersion in scores is observed. The ratio

TABLE II General results in the neuropsychological test battery

Variables	*Lowest*	*Highest*	*Mean*	*SD*
ATTENTION				
Icon Cancellation Test (ICT)				
Correct answers	7	16	14.9	1.8
Commission errors	0	21	0.2	1.7
Omissions errors	0	16	1.3	2.4
Total errors	0	29	1.5	3.3
Time	19	155	51.9	24.6
Square Cancellation Test (SCT)				
Correct answers	0	48	39.8	7.0
Commission errors	0	62	0.9	5.9
Omission errors	0	48	8.7	7.9
Total errors	0	67	9.6	9.5
Time	15	420	143.4	60.3
MEMORY				
Nonverbal Selective Reminding (NSVR)				
First Trial	0	8	4.2	2.0
Maximum score	3	8	7.4	1.8
Delayed recall	0	8	6.5	2.0
Number of trials	1	5	3.7	1.4
Figure Memory Test (FMT)				
Immediate recall	10	23	19.9	2.4
Recall after interference	10	23	19.6	2.6
Semantic Cued Recall Memory (SCRM)				
Delayed recall 1 (after 5 minutes)	3	16	14.3	2.3
Delayed recall 2 (after 20 minutes)	5	16	14.5	2.2
VISUOPERCEPTUAL AND VISUO-CONSTRUCTIVE				
Motor Free Visual Perception (MVPT)	20	36	33.0	3.4
Overlapping Figures	14	20	19.5	1.1
To Match Faces	2	7	5.7	0.7
WAIS				
Block Design	8	48	29.4	9.0
Picture Arrangement	4	34	17.1	6.8
Drawing				
Command	0	9	5.2	2.4
Copy	4	50	39.0	9.1
EXECUTIVE FUNCTION				
WCST-Abbreviated				
Correct answers	0	41	23.5	8.4
Errors	7	48	24.2	8.6
Categories	0	6	2.9	1.5
Nonperseverative Errors	0	33	8.8	4.7
Perseverative Errors	2	46	15.4	7.7
OTHER NONVERBAL ABILITY TESTS				
Praxis	20	40	37.9	3.0
Written Calculations	17	50	45.6	5.2

between the highest and the lowest test score is variable. In some tests this ratio was below 2.0 (*e.g.*, Overlapped Figures), whereas in other tests, it was over 10.0 (*e.g.*, WCST–Perseverative Errors).

Using a factor analysis with a Varimax orthogonal rotation, four exploratory factor analyses were carried out. Attention test scores (10 variables) were grouped into three factors, accounting for 73.1% of the test variance. Three test scores from the Icon Cancellation Test are significantly saturated by this factor (*Sustained Attention* or *Vigilance* factor) accounting for 34% of the variance. Considering that the Icon Cancellation Test score is negatively related with this factor, whereas errors is positively related, it can be assumed that this factor refers to a deficiency in vigilance. In the second factor, three scores from the Square Cancellation Test were included (*Divided and Alternating Attention* factor) and account for 20.5% of the variance. Errors negatively load this factor, and in consequence the factor refers to a defect in divided and alternating attention. Factor 3 includes the time scores in the ICT and SCT, and it is in consequence a *Processing Speed* factor, accounting for 18.2% of the variance (Tab. III).

Two stable factors were found in the memory tests (Tab. IV). Factor 1 included the two conditions of the FMT and accounts for 42.4% of the variance (*Categorical Visual Memory* factor). Factor 2 refers to memory of dots in a space (NSVT) and may be interpreted

TABLE III Factor analysis using the two attention tests (10 variables). An orthogonal varimax rotation was used

Variables	*Communality*	*Factor 1 eigenvalue* 3.4 *% variance* 34.4	*Factor 2 eigenvalue* 2 *% variance* 20.5	*Factor 3 eigenvalue* 1.8 *% variance* 18.2
ICT: Total errors	0.94	0.95		
ICT: Omission errors	0.90	0.95		
ICT: Correct answers	0.84	−0.91		
SCT: Omissions errors	0.89		0.93	
SCT: Total errors	0.89		0.90	
SCT: Correct answers	0.60		−0.77	
ICT: Time	0.66			0.77
SCT: Time	0.54			0.73
ICT: Commission errors	0.57			0.67
SCT: Commission errors	0.47			0.61

TABLE IV Factor analysis using the three nonverbal memory test (8 variables). An orthogonal varimax rotation was used

Variables	*Communality*	*Factor 1 eigenvalue* 3.3 *% variance* 42.4	*Factor 2 eigenvalue* 1.3 *% variance* 17.3
FMT: Immediate recall	0.78	0.88	
FMT: Recall after interference	0.74	0.86	
SCRM: Delayed recall 2	0.60	0.69	0.35
SCRM: Delayed recall 1	0.59	0.69	0.34
NSVR: Maximum score	0.68		0.79
NSVR: Delayed recall	0.53		0.72
NSVR: Number of trials	0.47		0.66
NSVR: First trial MVEP	0.36		0.55

as a *Noncategorical Visual Memory* factor. It accounts for 17.3% of the variance.

Two stable factors were found in visuoperceptual and visuoconstructive test scores. Drawing–both conditions, Block Design and MVPT were most saturated by this factor (*Visuoconstructive* factor). Whereas Overlapping Figures and Matching Faces were most saturated by the second factor (*Simultaneous Visual Recognition*) accounting for 17.5% of the variance (Tab. V).

Two factors were found in the WCST. In the first one, Perseverative Errors was positively saturated by this factor and Categories was negatively saturated. It accounts for almost two-thirds of the variance (*Flexible Classification*). Non Perseverative Errors was the

TABLE V Factor analysis using the visuoperceptual and visuoconstructive tests (7 variables). An orthogonal varimax rotation was used

Variables	*Communality*	*Factor 1 eigenvalue* 2.5 *% variance* 36.5	*Factor 2 eigenvalue* 1.2 *% variance* 17.5
Drawing: Copy	0.64	0.79	
MVPT	0.69	0.69	0.46
Drawing: Command	0.47	0.68	
Block Design	0.50	0.63	0.31
Overlapping Figures	0.59		0.76
To match faces	0.56		0.74

TABLE VI Factor analysis of the WCST (5 variables). An orthogonal varimax rotation was used

WCST Variables	*Communality*	*Factor 1 eigenvalue* 4.5 *% variance* 64.4	*Factor 2 eigenvalue* 1.2 *% variance* 17.6
Perseverative errors	0.96	0.97	
Correct answers	0.92	−0.90	−0.33
Errors	0.96	0.90	0.38
Categories	0.81	−0.77	−0.46
Nonperseverative errors	0.88		0.94

TABLE VII Confirmatory factor analysis using 13 variables. An orthogonal varimax rotation for noncorrelated variables was used. *Maximum Likelihood method* ($\chi^2 = 30.02$; $df = 23$; $p = .149$)

Factor	*Eigenvalue*	*% of variance*	*Cumulative variance*
1. Executive Function	3.9	30.0	30.0
2. Sequential–Constructional	1.9	14.7	44.7
3. Processing Speed	1.4	10.6	55.3
4. Visuoperceptual	1.2	9.5	64.8
5. Nonverbal Memory	1.0	7.8	72.6

only score significantly saturated by the second factor (*Trial/Error* factor) (Tab. VI).

Several exploratory factor analyses were carried out initially including the total 32 test scores. A sequential reduction of the variables was applied. Finally, using the procedure of Maximum Likelihood and calculating the χ^2 with a maximum likelihood (Goodness of Fit), a factorial model including only 13 variables (Goodness-of-fit: $\chi^2 = 30.02$, $df = 23$, $p = .14$) was selected. The selected factorial structure included five factors, and accounted for 72.6% of the variance (Tabs. VII and VIII). The first factor included three WCST scores, and was interpreted as an *Executive Function* factor. Written Calculations, Drawing–Copy, and the MVPT were highly saturated by the second factor. It was interpreted as a *Sequential–Constructional* factor, accounting for 14.7% of the variance. Factor 3 included time measures in the ICT and SCT, and hence, it represents a *Processing Speed* factor. The tests most saturated by factor 4 were Overlapping Figures and Matching Faces. Factor 4

TABLE VIII Confirmatory factor analysis

Variable	*Communality*	*Factor* 1	*Factor* 2	*Factor* 3	*Factor* 4	*Factor* 5
WCST Errors	0.94	0.95				
WCST Categories	0.87	−0.89				
WCST Perseverative errors	0.82	0.86				
Written calculations	0.54		0.87			
Drawing: Copy	0.78		0.81			
MVPT	0.64		0.70		0.42	
SCT: Time	0.60			0.80		
ICT: Time	0.71			0.76		
WCST: Nonperseverative errors	0.64	0.31		0.58		
Overlapping Figures	0.80				0.77	
To match faces	0.68				0.76	
FMT: Immediate recall	0.68		0.58			0.81
FMT: Recall after interference	0.73		0.68			0.73

was in consequence a *Visuoperceptual* factor (9.5% of the variance). Finally, Factor 5 (7.8% of the variance) was a *Nonverbal Memory* factor. FMT Immediate recall and SCRM Delayed Recall 2 were most saturated by this memory factor. The factors clearly corresponded to domains included in testing: attention, executive function, memory, visuoperceptual and visuoconstructive abilities.

DISCUSSION

Five relatively independent nonverbal cognitive factors were found in the final confirmatory factor analysis: attention (*Processing Speed* factor), memory (*Nonverbal Memory* factor), visuoperceptual and visuoconstructive (*Sequential–Constructional* and *Visuoperceptual* factor), and executive function (*Executive Function* factor). In general, they coincide with the domains included in the test battery (*i.e.*, attention, memory, visuoperceptual and visuoconstructive, and executive function). The final factor analysis clearly separated visuoperceptual (Factor 4) from viusoconstructive abilities (Factor 2). The three test scores most saturated by the *Sequential–Constructional* factor were Written Calculations, Drawing: Copy condition, and the MVPT. As a matter of fact, Factor 2 could be interpreted as a kind of constructional–perceptual factor. It is important to emphasize that calculation ability in a significant extent represents not only a verbal but also nonverbal ability (Ardila, Galeano and Rosselli, 1998). In each domain (attention, memory, visuoperceptual and visuoconstructive, and executive function) two-to-three different factors (areas, or subfactors) were observed.

It may be conjectured that nonverbal cognition includes different systems (factors) somehow similar to the systems (factors) proposed by Luria (1976) to account for linguistic processes. It may be further assumed that there are common brain systems supporting the performance in those tests measuring a single factor (*e.g.*, Drawing: Copy and MVPT). Nonverbal cognition can be interpreted as including a series of intercorrelated functions (domains), or functional levels (Luria, 1966), that are activated according to the characteristics of the task (Ardila, 1995). Brain damage results in a disturbance at a specific level of the information processing. Evidently, the higher the correlation between two different tests, the higher should be the probability that they will be simultaneously impaired in cases of focal brain pathology, *i.e.*, higher probability that the abilities required to perform them successfully will share the same brain organization. Conversely, two low-correlated tests, saturated by two quite different factors (*e.g.*, Drawing: Copy and WCST: Errors) are expected to depend on the brain activity of quite different and distant brain areas. In the first case, the "functional distance" between the two tests is low; while in the second case it is high. "Functional distance" between two tests should be understood as the commonality in the brain organization of cognitive processes supporting their performance (Ardila, 1995).

Clinical observation supports the assumption that apparently different tasks (*e.g.*, to solve numerical problems and to recognize fingers) can be impaired as a consequence of the very same brain pathology. Certain "common factor" evidently should be contained in those apparently different, but simultaneously altered tasks in case of a single focal pathology (*e.g.*, to solve numerical problems and to recognize the fingers). If a "common factor" contributing to normal performance in two different cognitive tasks is disturbed in cases of focal brain pathology, it simply means that the factor (types of cognition) can be associated with the activity of a specific brain area or brain system.

When analyzing different domains, it was found that in each one different components (areas or subfactors) were found. Nonverbal attention included components related to Vigilance, Divided Attention, and Processing Speed. However, when a series of sequential factor analyses were performed, including tests from diverse cognitive domains, Vigilance and Divided Attention components disappeared and became included in one or several higher level factors. Thus, in the final confirmatory factor analysis, Vigilance and Divided Attention variables participated in Factors 1, 2, 4 and 5. The only attentional factor that remained as a stable and independent factor in the final factor structure was the Processing Speed factor, accounting for 10.6% of the whole test battery variance. This means that if only variables corresponding to the very same domain (*e.g.*, attention) are included in the factor analysis, then several factors can be found. But, if variables corresponding to different domains are included in the factor analysis, only the first initial and strongest factor (*e.g.*, *Processing Speed*) remains as an independent factor. A similar observation can be done with regard to memory and executive function.

Taking into account the nonverbal characteristics of the current neuropsychological test battery administered in this study, it was expected to find a visuospatial–visuoconstructional factor as the first and the most significant factor. A *Sequential–Constructional* (or Constructional–Perceptual) factor accounted for 14.7%, and a *Visuoperceptual* factor accounted for 9.5% of the total variance. Nonetheless, the first and most important factor was indeed an Executive Function factor (30% of the variance). This finding coincides with previous factor analytic studies of cognitive ability tests. Usually, the first factor is related to complex verbal abilities and executive functions (Ardila *et al.*, 1994; Ardila *et al.*, 1998; Ostrosky *et al.*, 1985, 1999, 1986; Ponton *et al.*, 1994). This converging evidence may suggest that the most influencing factor to account for the variance of cognitive constructs refers to a supraordering activity of the executed tasks (Brauer-Boone *et al.*, 1998), that is, an executive function factor. In the current research, it obviously was a nonverbal executive function factor.

We found in the WCST a factor structure quite similar to the factor structure reported by Greve *et al.* (1998) using a Varimax orthogonal rotation. They also found two factors: the first one was also related with some flexible classification (categories, errors, and perseverative errors); and the second one was related with a trial/error strategy (no perseverative errors and number of trials required to complete the six categories). In our study, the first factor accounted for about two-thirds of the variance, whereas the second one, for only 17.6% of the variance. Their relative weights, consequently, were quite uneven. Some authors have reported a three-factor structure (Paolo *et al.*, 1995; Sullivan *et al.*, 1993) but using somehow different statistical criteria. Our results do not support the WCST one-factor structure reported by other researchers (Bornstein, 1983; Goldman *et al.*, 1996; Swiercinsky and Hallenbeck, 1975; Wagman *et al.*, 1987). It is interesting to note, however, that in the final factor confirmatory analysis only Flexible Classification variables (categories, errors, and perseverative errors) were included, *i.e.*, only the variables of the first factor. It means only the variables of the first factor remained in the final confirmatory factor analysis.

Factor structure found in normal subjects may predict some clinical observations. Nonverbal Executive Function factor is obviously related to frontal lobe activity. Disturbances in this factor can be anticipated in cases of right frontal pathology. Factors 2 and 4 (Sequential–Constructional and Visuoperceptual) are expected to be related to right parietal and occipital activity, and disturbed in cases of pathology in these areas. This means potential clinical applications of statistical procedures used with normal populations can be anticipated. To some extent, clinical neuropsychological syndromes can be interpreted using a factor analytic approach.

There is no question that factor analysis of neuropsychological test performance can contribute to advancement in understanding the brain organization of cognition under normal and abnormal conditions. Much more research in the area, however, is obviously required.

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APPENDIX: NEUROPSYCHOLOGICAL TEST BATTERY

Attention

Icon Cancellation Test

Similar to the Letter Cancellation Test (Lezak, 1995). Sixteen icons alike those appearing in the Power Point program MsOffice 1995, file *wingdings*, were designed. Each icon was repeated 10 times. In the upper part of the testing sheet, the model to be crossed-out was presented. The subject was required to cross-out all the icons equal to the model. Correct answers (maximum = 16), commission errors, omission errors, total errors, and time were scored.

Square Cancellation Test

One hundred and forty small squares were used. Each one contained a line in a specific position. Ten types of squares were used, each one repeated 16 times. Three different types of squares were required to be crossed-out. The three target squares were presented in the upper part of the testing sheet. Correct answers (maximum = 48), commission errors, omission errors, and time were scored.

Memory

Nonverbal Selective Reminding (NSVR) (Breier et al., 1996)

The NSVR task involves memory for spatial location of a dot in a file of dots. The subject is show eight boxes, each containing a random array of five dots. A specific dot in each box is shown to the subject, who is asked to point to the particular dot in each box after all the boxes have been presented. The remainder of the test is analogous to the verbal selective reminding test in that the subject is reminded only of positions for incorrect responses but is required to give a response to all the boxes for seven subsequent trials. We used a sheet with nine dots for answering. We used only five trials. Once the subjects recalled the eight positions, the test was stopped. We also introduced a delayed recall after five minutes. Four different scores were used: First Trial (maximum score = 8), Maximum score (maximum score = 8), Delayed Recall (maximum score = 8), and Number of Trials (maximum score = 5).

Figure Memory Test (FMT)

Twenty-four figures drawn on a paper were presented during 30 seconds. Afterwards, a paper with 50 figures (the 24 intermixed with 26 new ones). The examiner pointed one by one, and the subject answered "yes" (it was included previously) or "not" (not previously presented). Further, an interfering task was used (cancellation tests) and a new similar trial was used. Each trial was scored (immediate and after interference) (maximum score = 24).

Semantic Cued Recall Memory (SCRM) (Pineda and Ardila, 1991)

Four cards were presented with four elements belonging to the same semantic category (animals, kitchen utensils, garments and fruits). Two delayed trials (5 and 20 minutes later) were used. The examiner presented the names of the semantic categories (written and orally) and the subject was asked to find out the correct figures on a card containing 50 figures drawn (16 correct and 34 incorrect). First and second recall trials were scored (maximum score = 16).

Visuospatial and Visuoconstructive Abilities

Motor Free Visual Perception (MVPT) (Coralusso and Hammill, 1980)

This test is composed of 36 cards grouped in five different conditions: (a) Visual Discrimination, (b) Spatial Relations, (c) Figure-Ground,

(d) Visual Conclusion and (e) Visual Memory. Only total score was used (maximum = 36).

Overlapping Figures Test (Poppelreuter, 1917; Ghent, 1956)

Five cards, each one containing for overlapping figures were used. It was taken form the Test de Evaluación Neuropsicológica de Barcelona (Peña-Casanova, 1990). (maximum score = 20).

To Match Faces

To match eight cartoon faces, taken from Test de Evaluación Neuropsicológica de Barcelona (Peña-Casanova, 1990). Correct answers were scored (maximum score = 8).

Block Design

Taken from the WAIS-Spanish version (Wechsler, 1988). Raw scores were used.

Picture Arrangement

Taken from the WAIS-Spanish version (Wechsler, 1988). Raw scores were used.

Drawing – Command

Taken from the nonverbal section of the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1986). A cross, a daisy, an elephant, a cube, a house and a clock (ten after ten) were used. It was scored according to the Manual (maximum score = 13).

Drawing – Copying

Five different models were presented with five details to be scored using a 0 to 2 scale (two-dimensional house, daisy, bicycle, cube and three-dimensional house). Then, each drawing was scored from zero (impossible) to ten (all the details included) (maximum score = 50).

Executive Function

Wisconsin Card Sorting Test (Heaton, 1981)

An abbreviated version was developed, using only two sets, each one containing 24 non-ambiguous cards. The following scores were used: Correct answers, Errors, Categories, Non Perseverative Errors and Perseverative Errors.

Praxis

Ideomotor Praxis

Twenty movements under verbal command were used, ten transitive, and ten nontransitive movements. Each movement was scored from zero (impossible) to two (correct). (maximum score = 40).

Calculation Abilities

Written Calculation

Twenty arithmetical operations, and reading of five Roman numerals were used. They were taken from the book *Diagnóstico de Daño Cerebral* (Ardila and Ostrosky, 1995). The number or errors were counted Each one was scored from zero (two or more errors, impossible) to 2 (correct). (maximum score was 50).