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Spanish Multicenter Normative Studies (NEURONORMA Project): Norms for the Visual Object and Space Perception Battery-Abbreviated, and Judgment of Line Orientation

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Abstract

This study forms part of the Spanish Multicenter Normative Studies (NEURONORMA project). Normative data for people aged over 49 years are presented for selected tasks of the visual object and space perception battery (VOSP) and for the judgment of line orientation (JLO) test. Age-adjusted norms were derived from a sample of 341 participants who are cognitively normal and community-dwelling. Age- and education-adjusted norms are also provided. Years of education were modeled on age-scaled scores to derive regression equations that were applied for further demographic adjustments. The normative information provided here should prove useful for characterizing and interpreting individual test performances as well as comparing the scores from these tests with any other test using NEURONORMA norms.

Keywords: Age factors; Demography; Educational status; Reference values; Pattern recognition/visual; Space perception/physiology

Introduction

Disturbances of object and space perception are among the salient behavioral consequences of brain lesions (Benton, Hamsher, Varney, & Spreen, 1983; Benton, Sivan, Hamsher, Varney, & Spreen, 1994). The assessment of visual object and space perception forms part of any comprehensive neuropsychological assessment because vision has two main goals: the identification of stimuli and their localization (Farah, 2003). The Spanish Multicenter Normative Studies (NEURONORMA project) (Peña-Casanova et al., 2009) attempts to provide normative and psychometric information for

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people aged over 49 years for commonly used neuropsychological tests. In this paper we provide normative data for the visual object and space perception battery (VOSP) (Warrington & James, 1991), and the judgment of line orientation (JLO) (Benton, Hannay, & Varney, 1975, Benton, Varney, & Hamsher 1978; Benton et al., 1994).

Visual Object and Space Perception Battery

This is a battery of eight tests developed to assess object and space perception. The test is based on the theoretical proposal that object and space perception is functionally and anatomically independent, and may be dissociated in the case of brain lesions. It is based upon Warrington's model (McCarthy & Warrington, 1990), which distinguishes three subtypes of impaired object recognition: (a) disorders of visual sensory discrimination; (b) apperceptive agnosia; and (c) associative agnosia. Warrington's theory of visual processing and the VOSP were validated by Rapport, Millis, and Bonello, (1998). Further studies using the VOSP indicate that object decision is not a single task or ability and is not necessarily independent of conceptual knowledge (Hovius, Kellenbach, Graham, Hodges, & Paterson, 2003), so that a rigid separation between perceptual and semantic mechanisms may be unwarranted (Binetti et al., 1996).

The battery includes one screening test of visual shape detection to ensure that patients have adequate visual-sensory capacities. The VOSP consists of the following tests: four subtests for object perception (Tests 1–4: incomplete letters, silhouettes, object decision, and progressive silhouettes) and four for space perception (Test 5–8: dot counting, position discrimination, number location, and cube analysis).

Several normative data have been published (Strauss, Sherman, & Spreen, 2006), including preliminary data on children (Weber, Pache, Lutschg, & Kaiser, 2004). A preliminary Spanish normative study has also been recently published (Herrera-Guzmán et al., 2004). The results of this study correspond to others that provide evidence of the importance of sociodemographic variables when performing specific object and spatial visual perception tasks. The influence of age and education appeared to be very similar to the American sample of Bonello and colleagues (1997).

Performance on VOSP diminishes with age (Herrera-Guzmán, et al., 2004; Warrington & James, 1991). The failure to observe age-related declines on some tasks (dot counting, incomplete letters, and position discrimination) is probably due to ceiling effects. A differential progression of the effect of aging has been proposed in which object perception declines earlier than space perception (Bonello et al., 1997). Education effects have been reported to be weak but significantly associated with several tasks (Bonello et al., 1997; Herrera-Guzmán, et al., 2004).

Sex shows contradictory results. Bonello and colleagues (1997) reported that it did not affect performance while Spanish preliminary data (Herrera-Guzmán et al., 2004) indicated sex-related differences in five tasks (silhouettes, object decision, progressive silhouettes, position discrimination, and cube analysis).

Judgment of Line Orientation

This test measures spatial perception and orientation. It assesses the ability to estimate angular relationships between line segments by visually matching angled line pairs to 11 numbered radii forming a semicircle. The test consists of 30 items, each showing a different pair of angled lines to be matched to the display cards. The score is the number of items in which judgments for both lines are correct. A number of short forms have been presented (Mount, Hoog, & Johnstone, 2002; Qualls, Bliwise, & Stringer 2000; Vanderploeg, LaLone, Greblo, & Schinka, 1997; Winegarden, Yates, Moses, Benton, & Faustman, 1998; Woodard et al., 1996; Woodard, Benedict, Roberts, et al. 1998).

There are a number of studies that provide normative data for different populations (*see* Mistrushina, Boone, Razani & D'Elia 2005; Strauss et al., 2006). These include norms from the MOANS project (Ivnik, Malec, Smith, Tangalos, & Petersen, 1996) and Spanish data (Montse, Pere, Carme, Francesc, & Eduardo, 2001) pertaining to a control group in a study of Parkinson's disease patients.

Whilst the effects of age and sex have consistently been reported in the JLO literature, the impact of education on JLO performance has been equivocal. Age shows a relationship with test scores (Benton et al., 1994), implying that performance declines with age (Eslinger & Benton, 1983; Ivnik et al., 1996; Mittenberg, Seidenberg, O'Leary, & DiGuilio, 1989; Montse et al., 2001). Salthouse, Toth, Hancock, and Woodard (1997) when using the short version did not, however, find this relationship between age and JLO performance.

Sex effects have been demonstrated by a series of studies in which men performed better (two points higher) than women (for example, Basso & Lowery, 2004; Basso, Harrington, Matson, & Lowery, 2000; Benton et al., 1994; Desmond, Glenwich, Stern, & Tatemichi, 1994; Glamser & Turner, 1995; Montse et al., 2001; Riva & Benton, 1993). The observed sex differences may reflect fundamental differences in brain organization. Gur and colleagues (2000) showed that while the line orientation task activated both hemispheres in men it chiefly acted on the right hemisphere in women. This suggests a supplementary cognitive process carried out by the left hemisphere in men.

The influence of formal education on test performance is particularly clear in tests of visuospatial perception (Lezak, Howieson, & Loring, 2004; Mazaux et al., 1995). In JLO performance, some studies (Ivnik et al., 1996; Lucas et al., 2005) observed a modest impact of education in older adults, whereas Benton and colleagues (1994) found better scores in higher educated elderly people.

Materials and Methods

Research Participants

Sample characteristics, recruitment procedures, and general methods of the NEURONORMA project have been reported in a previous paper (*see* Peña-Casanova et al., 2009). The project was reviewed and approved by the Research Ethics Committee of the Municipal Institute of Medical Care of Barcelona, Spain. Participants were recruited from nine services of neurology and units of neuropsychology in different Spanish regions. Study participants (people aged over 49 years) were identified as normal based on criteria established for NEURONORMA project. The following tools were used in the process of selection and classification of study participants: (a) *Mini mental state examination* (MMSE) (Folstein, Folstein, & McHugh, 1975 [validated Spanish version (Blesa et al., 2001)]). This version provides an adjustment of the scores according to age and education; (b) *Interview for deterioration of daily living in dementia* (IDDD) (Teunisse, Derix, & Crever, 1991; Böhm et al., 1998 [validated Spanish version]). This scale measures functional disability in self-care (16 items) and complex activities (17 items); (c) *Hamilton depression rating scale* (HDRS) (Hamilton, 1960). This is a semi-structured interview to assess the severity of depression for clinical research. A 17-item Spanish version was used; (d) *Modified ischemia score* (Rosen, Terry, Fuld, Katzman, & Peck, 1980). Administered to assess cerebrovascular risk. A cut-off of four was considered appropriate.

Volunteers did not need to be completely medically healthy to participate. Subjects with active, chronic medical, psychiatric, or neurological conditions or with physical disabilities were included if the researcher judged that the condition was correctly controlled or resolved and did not cause cognitive impairment.

Demographic information concerning the VOSP and JLO is presented in Table 1.

Table 1. Sample size by demographics and test

	VOSP		JLO	
	Count	Percent of Total	Count	Percent of Total
Age group				
50–56	74	21.70	76	22.29
57–59	51	14.96	50	14.66
60–62	34	9.97	33	9.68
63–65	15	4.40	15	4.40
66–68	26	7.62	26	7.62
69–71	49	14.37	49	14.37
72–74	33	9.68	32	9.38
75–77	28	8.21	29	8.50
78–80	20	5.86	21	6.16
>80	11	3.23	10	2.93
Education (years)				
≤5	72	21.11	71	20.82
6–7	23	6.74	23	6.74
8–9	65	19.06	65	19.06
10–11	41	12.02	41	12.02
12–13	35	10.26	33	9.68
14–15	32	9.38	33	9.68
≥16	73	21.41	75	21.99
Sex				
Male	137	40.18	139	40.76
Female	204	59.82	202	59.24
Total Sample	341		341	

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Neuropsychological Measures

The neuropsychological measures were administered as part of a larger test battery, the NEURONORMA battery (Peña-Casanova et al., 2009). Tests were administered and scored by neuropsychologists specifically trained for this project.

Visual object and space perception battery

Considering data from a previous Spanish preliminary study (Herrera-Guzmán et al., 2004), the following tests were selected: *Shape Detection* (a screening test to ensure that participants have adequate visual-sensory capacities); two tests for object perception: *object decision* (Test 3) and *progressive silhouettes* (Test 4); and two tests for space perception: *position discrimination* (Test 6) and *number location* (Test 7). Each test was preceded by two practice items. The total number of correct items was scored.

Shape detection screening test. As visual object and space perception can only be meaningfully assessed in participants with adequate visual sensory capacities, a screening test was administered to ensure basic visual-sensory capacities. The test consists of 20 random pattern stimuli on half of which a degraded X is superimposed. The participant is required to judge whether the X is present. The total number of correct responses is scored, summing up the false positive and the false negative. According to the test manual, subjects with a score of 15 or lower should not be further tested.

Object decision (Test 3). This test consists of 20 arrays, each of which displays one real two-dimensional object together with three distracter items. The subject is required to identify the real object shown at an angle of rotation at which it could be identified by approximately 75% of a normal control group. The number of correct choices (maximum 20) is recorded.

Progressive silhouettes (Test 4). This test consists of two series of stimulus cards (depicting a gun and a trumpet), each comprised of 10 silhouette drawings. Each successive drawing progressively reveals more details of the object. The subject is required to identify the object as early as possible. The number of trials required to identify each object is totaled and recorded as the score. Maximum score is 20 (10 + 10).

Position discrimination (Test 6). This test consists of 20 cards. Each card contains two adjacent squares containing dots: one with a black dot printed exactly in the center and one with the black dot just off-center. The participant has to decide which square has the dot in the center. The number of correct choices is recorded as the score (maximum score is 20).

Number location (Test 7). This test consists of 10 cards. Each card shows two squares, one above the other with a small gap between them. The top square contains randomly placed numbers (1–9) and the bottom square contains a single black dot corresponding to the position of one of the numbers. The task is to identify the number that corresponds with the position of the dot. The total number of correct responses is recorded (maximum score is 10).

The selected tests of the VOSP were administered following instructions as described in the test manual (Warrington & James, 1991).

Judgment of Line Orientation

The test (form H) was administered following instructions as described in the test manual (Benton et al., 1983). In all cases, five sample practice items were administered prior to the presentation of the actual 30 test items. If, after 30 s, a participant had not given a response he/she was encouraged to make his/her best guess regardless of how uncertain he/she was about it. Spontaneous corrections by the participant were accepted (maximum score is 30).

Statistical Analysis

The procedure is described previously in a study by Peña-Casanova and colleagues (2009). In summary, the principal characteristics of this process were the following: (a) the overlapping interval strategy (Pauker, 1988) was adopted to maximize the number of participants contributing to the normative distribution at each mid-point age interval; (b) effects of age, sex, and education effects on raw subtest scores were studied using coefficients of correlation (r) and determination (r^2) (Lucas et al., 2005); (c) to ensure a normal distribution, the frequency distribution of the raw scores was converted into age-adjusted scaled scores, NSS_A (NEURONORMA Scaled Score-age adjusted) following the methodology described by Ivnik and colleagues (1992). Raw scores were assigned percentile ranks in function of their place within a distribution. Subsequently, percentile ranks were converted to scaled scores (from 2 to 18) based on percentile ranges. This transformation of raw scores to NSS_A produced a normalized distribution, on which linear regressions could be applied; (d) years of education were modeled with the following equation:

$$NSS_A = k + (\beta * \text{Educ}) \tag{1}$$

The resulting equations were used to calculate age- and education-adjusted NEURONORMA scaled scores ($NSS_{A\&E}$) for each variable. The regression coefficients (β) from this analysis were used as the basis for education adjustments. A linear regression was employed to derive age- and education-adjusted scaled scores. The obtained NSS_A score was adjusted by the difference between the predicted scores based upon the subject's actual education and the predicted score given 12 years of education (selected because it provided a relatively standard reference point) (Mungas, Marshall, Weldon, Haan, & Reed, 1996). The reason for this methodological election was that provided a better standard reference, with a mean and a very similar *SD* to the distribution of NSS_A. The following formula outlined by Mungas and colleagues (1996) was employed

$$NSS_{A\&E} = NSS_A - (\beta * [Educ - 12]) \tag{2}$$

The formula to calculate NEURONORMA scaled score-adjustment for age, education, and sex ($NSS_{A\ \&\ E\ \&\ S}$) was the following:

$$NSS_{A\&E\&S} = NSS_A - (\beta * [Education_{(years)} - 12]) - (\gamma * Sex)) \tag{3}$$

Results

Sample sizes resulting from mid-point age intervals are presented in each normative table. Correlations and shared variance of the VOSP scores and the JLO-derived scores, with age, education, and sex are presented in Table 2.

Concerning VOSP, age accounted for 9% for the raw score variance for progressive silhouettes (Test 4). Age effect was minimal or nonexistent for the other tests ($\leq$3%). Education accounted significantly and discretely for the raw score variance for all measures (4–9%). Sex differences were not observed, indicating no need to control this demographic variable.

Concerning JLO, the data given in Table 2 show that age accounts for only 3% of the shared variance while education has a more important effect (18%). Sex accounts for 5% of the raw score variance, indicating that adjustments for sex are appropriate.

Age-adjusted NEURONORMA scaled scores (NSS_A) for the VOSP and JLO are presented in Tables 3–12. These tables include percentile ranks, ranges of ages contributing to each normative sub-sample, and the number of participants contributing to each test's normative estimates. To use the table, select the appropriate column corresponding to the patient's age, find the patient's raw score, and subsequently refer to the corresponding NSS_A and percentile rank (left part of the tables).

As expected, the normative adjustments (NSS_A) eliminated the shared variance of age (Table 13). Education, however, continued to account for up to 5–9% (rounded) of shared variance with age-adjusted test scores for the VOSP, and up to 14% for the JLO. To maintain the same analysis, education adjustments were applied to all variables. For the JLO, sex continued to account for an 8% ($r = -2.27863$; $r^2 = 0.077635$) of shared variance after age adjustment.

The transformation of RS to NSS_A produced a normalized distribution on which linear regressions could be applied. Regression coefficients from this analysis were used as the basis for education adjustments. The resulting computational formulae were used to calculate $NSS_{A\&E}$. From these data, we have constructed correction tables to help the clinician make the necessary adjustment (Tables 14–17 for VOSP). Values of β are included in these tables. For the JLO we have constructed correction tables for both sexes (Tables 18 and 19). The formula (3) to calculate NEURONORMA scaled score-adjustment for age, education, and sex ($NSS_{A\&E\&S}$) was applied using the following data: $\beta = 0.119405$, $\gamma = -1.37869$, and sex 0 (=man) or 1 (=woman).

Table 2. Correlations (r) and shared variances (r^2) of raw scores with age, year of education, and sex

Variables	Age (years)		Education (years)		Sex	
	r	r^2	r	r^2	r	r^2
VOSP						
Test 3: Object Decision	−0.18653	0.03479	0.28322	0.08021	−0.07615	0.0058
Test 4: Progressive Silhouettes	0.30345	0.09208	−0.31588	0.09978	0.08851	0.00783
Test 5: Position Discrimination	−0.05721	0.00327	0.2	0.04	−0.06646	0.00442
Test 7: Number Location	−0.12549	0.01575	0.31181	0.09723	−0.05466	0.00299
JLO						
Form H. Raw score	−0.19848	0.03939	0.42822	0.18337	−0.23902	0.05713

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 3. Age-adjusted NEURONORMA scores (NSS_A) for age 50–56 (age range for norms = 50–60) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	10	16	11	3	12
3	1	—	—	—	—	14
4	2	11	15	—	4	15
5	3–5	12	—	17	—	—
6	6–10	—	14	18	6	16–17
7	11–18	13–14	13	—	7	18–19
8	19–28	15	—	19	8	20
9	29–40	16	12	—	—	21–22
10	41–59	17	10–11	—	9	23–24
11	60–71	—	9	—	—	25–26
12	72–81	18	8	—	—	27
13	82–89	—	7	—	—	28
14	90–94	19	—	—	—	—
15	95–97	—	6	—	—	29
16	98	—	—	—	—	—
17	99	—	5	—	—	—
18	>99	20	4	20	10	30
Sample Size		135	135	135	135	135

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 4. Age-adjusted NEURONORMA scores (NSS_A) for age 57–59 (age range for norms = 53–63) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	9	18	13	3	8
3	1	10	16	—	—	—
4	2	—	—	—	—	10
5	3–5	11	15	—	4–5	12–14
6	6–10	12	—	17–18	6	15–16
7	11–18	13	14	—	7	17–18
8	19–28	14	13	19	8	19
9	29–40	15–16	12	—	—	20–21
10	41–59	—	11	—	9	22–23
11	60–71	17	10	—	—	24–25
12	72–81	18	8–9	—	—	26
13	82–89	—	7	—	—	27
14	90–94	19	—	—	—	28
15	95––97	—	6	—	—	29
16	98	—	—	—	—	—
17	99	—	5	—	—	—
18	>99	20	4	20	10	30
Sample Size		133	133	133	133	131

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

To use Tables 14–19 select the appropriate column corresponding to the patient's years of education, find the patient's NSS_A, and subsequently refer to the corresponding $NSS_{A\&E}$, or $NSS_{A\&E\&S}$. When these formulas were applied to the NEURONORMA normative sample, the shared variances between demographically adjusted NEURONORMA scaled scores, years of education, and sex fell to $<1\%$.

Discussion

The purpose of this report was to provide normative and comprehensive data for older Spaniards for the selected tests of the VOSP and JLO. Age-adjusted normative data and regression-based adjustments for education and sex are presented. This study

Table 5. Age-adjusted NEURONORMA scores (NSS_A) for age 60–62 (age range for norms = 56–66) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	9	18	13	—	8
3	1	10	16	16	3	—
4	2	—	—	—	—	10
5	3–5	11	15	17	4	12–15
6	6–10	12	—	18	5	16–17
7	11–18	13	14	—	6	18
8	19–28	14	13	19	7	19–20
9	29–40	15	—	—	—	21
10	41–59	16	11–12	—	8	22–23
11	60–71	17	10	—	9	24–25
12	72–81	18	9	—	—	26–27
13	82–89	—	8	—	—	28
14	90–94	19	7	—	—	—
15	95–97	—	6	—	—	29
16	98	—	—	—	—	—
17	99	—	—	—	—	—
18	>99	20	4	20	10	30
Sample Size		121	121	121	121	119

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 6. Age-adjusted NEURONORMA scores (NSS_A) for age 63–65 (age range for norms = 59–69) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	—	18	13	—	8
3	1	9	16	—	—	—
4	2	10	—	—	3	10
5	3–5	—	—	16	4	12–15
6	6–10	11–12	15	17	5–6	16–17
7	11–18	13	14	18	7	18
8	19–28	14	13	19	—	19–20
9	29–40	15	—	—	8	21
10	41–59	16–17	11–12	—	9	22–23
11	60–71	—	10	—	—	24–25
12	72–81	18	9	—	—	26–27
13	82–89	—	7–8	—	—	28
14	90–94	19	—	—	—	—
15	95–97	—	6	—	—	29
16	98	—	—	—	—	—
17	99	—	—	—	—	—
18	>99	20	4	20	10	30
Sample Size		104	104	104	104	103

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

offers for the first time systematic, normative information for Spanish subjects aged over 49 years on the selected test of the VOSP.

Visual Object and Space Perception Battery

This study includes considerably more subjects than in the previous Spanish study by Herrera and colleagues (2004) and in other normative studies (Bonello et al., 1997; Warrington & James, 1991). As a consequence, the data presented for the analysis of demographic effects on the scores of the selected test studied in the NEURONORMA project are more consistent. Unfortunately, not all VOSP tests are included in the NEURONORMA project.

Table 7. Age-adjusted NEURONORMA scores (NSS_A) for age 66–68 (age range for norms = 62–72) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	—	18	13	—	8
3	1	9	—	—	3	—
4	2	10	17	—	4	10
5	3–5	11	16	16	5	12–13
6	6–10	12	15	17–18	6	15–16
7	11–18	13	14	—	7	17–18
8	19–28	14	13	19	—	19–20
9	29–40	15	—	—	8	21
10	41–59	16	11–12	—	9	22–24
11	60–71	17	—	—	—	25
12	72–81	18	9–10	—	—	26–27
13	82–89	—	—	—	—	28
14	90–94	19	7–8	—	—	29
15	95–97	—	6	—	—	—
16	98	—	—	—	—	—
17	99	—	5	—	—	—
18	>99	20	4	20	10	30
Sample Size		119	119	119	119	119

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 8. Age-adjusted NEURONORMA scores (NSS_A) for age 69–71 (age range for norms = 65–75) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	7	18	—	—	12
3	1	9	—	—	—	—
4	2	—	17	—	3	—
5	3–5	10–11	16	16	4–5	13–14
6	6–10	12	15	17–18	6	15–16
7	11–18	13	14	—	7	17–18
8	19–28	14	13	19	8	19–20
9	29–40	15	—	—		21–22
10	41–59	16	11–12	—	9	23–24
11	60–71	17	—	—	—	25
12	72–81	18	9–10	—	—	26
13	82–89	19	8	—	—	27–28
14	90–94	—	7	—	—	29
15	95–97	—	6	—	—	—
16	98	—	5	—	—	—
17	99	—	—	—	—	—
18	>99	20	4	20	10	30
Sample Size		126	126	126	126	125

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

We confirm that the object decision and progressive silhouettes tests scores show a normal distribution, but the position discrimination and number location tests do not (*see* Herrera-Guzmán et al., 2004). This fact is reflected in mid-point (boldface numbers) in Tables 3–12, and affects the correct use of the overall NEURONORMA analysis method based on normal distributions. This problem is also observed in other neuropsychological tasks such as digit repetition (*see* Peña-Casanova et al., 2009) or in some subtests of the WMS-R norms in the MOANS project (e.g., Ivnik et al., 1992; Lucas et al., 2005). To minimize this problem, some authors suggest to deal with the data in raw scores form than to convert them into scaled scores (Lezak et al., 2004). We certainly agree with that proposition and recognize the statistical problems of forcing these kinds of scores into a normal distribution. However, given the characteristics and purposes of this normative project, we chose to homogenize the statistical analysis procedure. Further to this we developed normative data following the single procedure described by the Mayo Clinic researchers (*see* Ivnik et al., 1992).

Table 9. Age-adjusted NEURONORMA scores (NSS_A) for age 72–74 (age range for norms = 68–78) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	7	18	—	—	12
3	1	9	—	—	3	—
4	2	10	17	—	4	—
5	3–5	11	16	16–17	5	13–14
6	6–10	12	15	18	6	15–16
7	11–18	13	14	—	7	17
8	19–28	14	—	19	8	18–19
9	29–40	15	13	—	—	20
10	41–59	16	12	—	9	21–23
11	60–71	17	11	—	—	24–25
12	72–81	–	10	—	—	26
13	82–89	18	9	—	—	27
14	90–94	19	8	—	—	28–29
15	95–97	—	6–7	—	—	—
16	98	—	—	—	—	—
17	99	—	5	—	—	—
18	>99	20	—	20	10	30
Sample Size		124	124	124	124	125

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 10. Age-adjusted NEURONORMA scores (NSS_A) for age 75–77 (age range for norms = 78–81) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	—	18	—	—	—
3	1	7	—	16	—	—
4	2	—	17	—	3	12
5	3–5	10–11	16	—	4–5	—
6	6–10	12	—	17–18	6	13–14
7	11–18	13	15	—	7	15–16
8	19–28	14	14	19	8	17–18
9	29–40	15	13	—	—	19–20
10	41–59	16	12	—	—	21–22
11	60–71	17	11	—	9	23–24
12	72–81	–	10	—	—	25–26
13	82–89	18	9	—	—	27
14	90–94	19	8	—	—	28
15	95–97	—	6–7	—	—	29
16	98	—	5	—	—	—
17	99	—	—	—	—	—
18	>99	20	—	20	10	30
Sample Size		99	99	99	99	100

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Education showed a more consistent effect than age on the raw scores of the VOSP (*see* Table 2). The progressive silhouettes test was the most sensitive to these variables (9% of the shared variance for both age and education).

We do not confirm previous Spanish data (Herrera-Guzmán et al., 2004) on the effect of sex on the selected tests studied in this project. It is noteworthy that in the Spanish preliminary study sex-related differences were found in five of the eight tasks: silhouettes, object decision, progressive silhouettes, position discrimination, and cube analysis.

Judgment of Line Orientation

Our results concerning demographic variables show the same tendencies as in the MOANS projects (Lucas et al., 2005; Steinberg, Bieliauskas, Smith, Langellotti, & Ivnik, 2005). This study shows a very low effect of age for the raw score variance

Table 11. Age-adjusted NEURONORMA scores (NSS_A) for age 78–80 (age range for norms = 74–84) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	—	18	—	—	—
3	1	7	—	—	—	12
4	2	—	17	—	—	—
5	3–5	10	16	—	3–4	—
6	6–10	11	15	17–18	6	13
7	11–18	12–13	—	—	—	15–16
8	19–28	—	14	—	7	17
9	29–40	14	—	19	8	18–19
10	41–59	15–16	13	—	—	20–21
11	60–71	17	12	—	9	22–23
12	72–81	—	11	—	—	24
13	82–89	18	10	—	—	25
14	90–94	—	9	—	—	27
15	95–97	19	8	—	—	28
16	98	—	—	—	—	—
17	99	—	5	—	—	—
18	>99	20	—	20	10	30
Sample Size		62	62	62	62	131

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 12. Age-adjusted NEURONORMA scores (NSS_A) for age 81–90 (age range for norms = 77–90) for VOSP and JLO

Scaled Score	Percentile Range	VOSP				JLO
		Object Decision	Progressive Silhouettes	Position Discrimination	Number Location	
2	<1	—	17	—	—	—
3	1	—	—	—	—	—
4	2	10	—	13	4	12
5	3–5	11	16	—	6	13
6	6–10	–	15	17	—	15
7	11–18	12	—	18	—	16
8	19–28	13	14	19	7	17
9	29–40	14	—	—	8	18–19
10	41–59	15–16	13	—	—	20
11	60–71	17	12	—	9	21–22
12	72–81	—	11	—	—	23–24
13	82–89	18	10	—	—	25
14	90–94	—	—	—	—	27
15	95–97	19	9	—	—	28
16	98	—	8	—	—	—
17	99	—	—	—	—	—
18	>99	20	—	—	—	30
Sample Size		39	39	39	39	40

Notes: JLO = judgment of line orientation; VOSP = visual object and space perception battery.

Table 13. Correlations (r) and shared variances (r^2) of age-adjusted NEURONORMA scores (NSS_A) with age, and education (years)

Variables	Age (years)		Education (years)	
	r	r^2	r	r^2
VOSP				
Test 3: Object Decision	−0.03385	0.00115	0.22831	0.05213
Test 4: Progressive Silhouettes	0.05663	0.00321	−0.24652	0.06077
Test 5: Position Discrimination	−0.04521	0.00204	0.21443	0.04598
Test 7: Number Location	−0.10526	0.01108	0.29663	0.08799
JLO				
Form H. Raw score	−0.01146	0.00013	0.38576	0.14881

Notes: JLO: Judgment of Line Orientation; VOSP Visual Object and Space Perception Battery.

Table 14. VOSP. Object decision test

NSS_A	Education (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	3	3	3	3	3	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	0
3	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	1
4	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2
5	6	6	6	6	6	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	3
6	7	7	7	7	7	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	4
7	8	8	8	8	8	7	7	7	7	7	7	7	7	6	6	6	6	6	6	6	5
8	9	9	9	9	9	8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	6
9	10	10	10	10	10	9	9	9	9	9	9	9	9	8	8	8	8	8	8	8	7
10	11	11	11	11	11	10	10	10	10	10	10	10	10	9	9	9	9	9	9	9	8
11	12	12	12	12	12	11	11	11	11	11	11	11	11	10	10	10	10	10	10	10	9
12	13	13	13	13	13	12	12	12	12	12	12	12	12	11	11	11	11	11	11	11	10
13	14	14	14	14	14	13	13	13	13	13	13	13	13	12	12	12	12	12	12	12	11
14	15	15	15	15	15	14	14	14	14	14	14	14	14	13	13	13	13	13	13	13	12
15	16	16	16	16	16	15	15	15	15	15	15	15	15	14	14	14	14	14	14	14	13
16	17	17	17	17	17	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	14
17	18	18	18	18	18	17	17	17	17	17	17	17	17	16	16	16	16	16	16	16	15
18	19	19	19	19	19	18	18	18	18	18	18	18	18	17	17	17	17	17	17	17	16

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta * [Education_{(years)} - 12])$, where $\beta = 0.13548$. VOSP = visual object and space perception battery.

Table 15. VOSP. Progressive silhouettes test

NSS_A	Education (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	3	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	0	0	0	0	0
3	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1
4	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2
5	6	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3
6	7	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	4	4	4	4	4
7	8	7	7	7	7	7	7	7	7	6	6	6	6	6	6	6	5	5	5	5	5
8	9	8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6	6	6
9	10	9	9	9	9	9	9	9	9	8	8	8	8	8	8	8	7	7	7	7	7
10	11	10	10	10	10	10	10	10	10	9	9	9	9	9	9	9	8	8	8	8	8
11	12	11	11	11	11	11	11	11	11	10	10	10	10	10	10	10	9	9	9	9	9
12	13	12	12	12	12	12	12	12	12	11	11	11	11	11	11	11	10	10	10	10	10
13	14	13	13	13	13	13	13	13	13	12	12	12	12	12	12	12	11	11	11	11	11
14	15	14	14	14	14	14	14	14	14	13	13	13	13	13	13	13	12	12	12	12	12
15	16	15	15	15	15	15	15	15	15	14	14	14	14	14	14	14	13	13	13	13	13
16	17	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	14	14	14	14	14
17	18	17	17	17	17	17	17	17	17	16	16	16	16	16	16	16	15	15	15	15	15
18	19	18	18	18	18	18	18	18	18	17	17	17	17	17	17	17	16	16	16	16	16

Notes: Education adjustment applying the following formula: $SSS_{AE} = SSS_A - (\beta * [Education_{(years)} - 12])$, where $\beta = 0.13188$. VOSP = visual object and space perception battery.

(3%) of the JLO. A fact that is reflected in the central tendency (NSS_A 10) of the mid-point tables: there is a progressive decrement of the raw scores in age 72–74 and beyond (from 23–24 points to 20). Our results confirm that formal education on JLO test performance is relatively modest (18% for the raw score variance) although psychometric adjustments are needed (*see* Benton et al., 1994; Ivnik et al., 1996; Lucas et al., 2005). We also confirm previous works (e.g., Basso & Lowery, 2004; Basso et al., 2000; Benton et al., 1994; Desmond et al., 1994; Glamser & Turner, 1995) that point out that male performance is slightly better in the JLO. Due to the fact that the effect of sex reached 5%, we decided to create specific adjustment tables for men and women.

Table 16. VOSP. Position discrimination test

NSS_A	Education (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	4	3	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	0	0	0
3	5	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	1	1	1
4	6	5	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	2	2	2
5	7	6	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	3	3	3
6	8	7	7	7	7	7	7	6	6	6	6	6	6	5	5	5	5	5	4	4	4
7	9	8	8	8	8	8	8	7	7	7	7	7	7	6	6	6	6	6	5	5	5
8	10	9	9	9	9	9	9	8	8	8	8	8	8	7	7	7	7	7	6	6	6
9	11	10	10	10	10	10	10	9	9	9	9	9	9	8	8	8	8	8	7	7	7
10	12	11	11	11	11	11	11	10	10	10	10	10	10	9	9	9	9	9	8	8	8
11	13	12	12	12	12	12	12	11	11	11	11	11	11	10	10	10	10	10	9	9	9
12	14	13	13	13	13	13	13	12	12	12	12	12	12	11	11	11	11	11	10	10	10
13	15	14	14	14	14	14	14	13	13	13	13	13	13	12	12	12	12	12	11	11	11
14	16	15	15	15	15	15	15	14	14	14	14	14	14	13	13	13	13	13	12	12	12
15	17	16	16	16	16	16	16	15	15	15	15	15	15	14	14	14	14	14	13	13	13
16	18	17	17	17	17	17	17	16	16	16	16	16	16	15	15	15	15	15	14	14	14
17	19	18	18	18	18	18	18	17	17	17	17	17	17	16	16	16	16	16	15	15	15
18	20	19	19	19	19	19	19	18	18	18	18	18	18	17	17	17	17	17	16	16	16

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta * [Education_{(years)} - 12])$, where $\beta = 0.17944$. VOSP = visual object and space perception battery.

Table 17. VOSP. Number location test

NSS_A	Education (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	5	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	0	0	0	0	−1
3	6	5	5	5	5	4	4	4	4	3	3	3	3	2	2	2	1	1	1	1	0
4	7	6	6	6	6	5	5	5	5	4	4	4	4	3	3	3	2	2	2	2	1
5	8	7	7	7	7	6	6	6	6	5	5	5	5	4	4	4	3	3	3	3	2
6	9	8	8	8	8	7	7	7	7	6	6	6	6	5	5	5	4	4	4	4	3
7	10	9	9	9	9	8	8	8	8	7	7	7	7	6	6	6	5	5	5	5	4
8	11	10	10	10	10	9	9	9	9	8	8	8	8	7	7	7	6	6	6	6	5
9	12	11	11	11	11	10	10	10	10	9	9	9	9	8	8	8	7	7	7	7	6
10	13	12	12	12	12	11	11	11	11	10	10	10	10	9	9	9	8	8	8	8	7
11	14	13	13	13	13	12	12	12	12	11	11	11	11	10	10	10	9	9	9	9	8
12	15	14	14	14	14	13	13	13	13	12	12	12	12	11	11	11	10	10	10	10	9
13	16	15	15	15	15	14	14	14	14	13	13	13	13	12	12	12	11	11	11	11	10
14	17	16	16	16	16	15	15	15	15	14	14	14	14	13	13	13	12	12	12	12	11
15	18	17	17	17	17	16	16	16	16	15	15	15	15	14	14	14	13	13	13	13	12
16	19	18	18	18	18	17	17	17	17	16	16	16	16	15	15	15	14	14	14	14	13
17	20	19	19	19	19	18	18	18	18	17	17	17	17	16	16	16	15	15	15	15	14
18	21	20	20	20	20	19	19	19	19	18	18	18	18	17	17	17	16	16	16	16	15

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta * [Education_{(years)} - 12])$, where $\beta = 0.26260$. VOSP = visual object and space perception battery.

Final Comments

This study offers, for the first time, Spanish normative data on the selected subtest of the VOSP, and JLO. These data were obtained from the same study sample as all other NEURONORMA norms. Cognitive normalcy was validated not only by applying inclusion and exclusion criteria, but also via informants (ADL scale) and a cognitive screening test (MMSE).

The validity of these norms is heavily dependent upon the similarity between the characteristics of the patient being assessed and the demographic, cultural, and linguistic features of the NEURONORMA sample (Ivnik et al., 1992). Education adjustments will help the clinician to obtain the rounded expected score by considering the number of years of formal education. In extreme cases the resulting adjustment may be placed beyond the defined scaled score range (e.g. 19 or 1). Under these

Table 18. JLO. Male

NSS_A	Education (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	4	4	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	0	0	0
3	5	5	4	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	1	1	1
4	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	2	2	2
5	7	7	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	3	3	3
6	8	8	7	7	7	7	7	6	6	6	6	6	6	5	5	5	5	5	4	4	4
7	9	9	8	8	8	8	8	7	7	7	7	7	7	6	6	6	6	6	5	5	5
8	10	10	9	9	9	9	9	8	8	8	8	8	8	7	7	7	7	7	6	6	6
9	11	11	10	10	10	10	10	9	9	9	9	9	9	8	8	8	8	8	7	7	7
10	12	12	11	11	11	11	11	10	10	10	10	10	10	9	9	9	9	9	8	8	8
11	13	13	12	12	12	12	12	11	11	11	11	11	11	10	10	10	10	10	9	9	9
12	14	14	13	13	13	13	13	12	12	12	12	12	12	11	11	11	11	11	10	10	10
13	15	15	14	14	14	14	14	13	13	13	13	13	13	12	12	12	12	12	11	11	11
14	16	16	15	15	15	15	15	14	14	14	14	14	14	13	13	13	13	13	12	12	12
15	17	17	16	16	16	16	16	15	15	15	15	15	15	14	14	14	14	14	13	13	13
16	18	18	17	17	17	17	17	16	16	16	16	16	16	15	15	15	15	15	14	14	14
17	19	19	18	18	18	18	18	17	17	17	17	17	17	16	16	16	16	16	15	15	15
18	20	20	19	19	19	19	19	18	18	18	18	18	18	17	17	17	17	17	16	16	16

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta * [Education_{(years)} - 12])$, where $\beta = 0.19405$. JLO = judgment of line orientation.

Table 19. JLO Female

NSS_A	Education (years)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	5	5	5	5	4	4	4	4	4	3	3	3	3	3	2	2	2	2	2	2	1
3	6	6	6	6	5	5	5	5	5	4	4	4	4	4	3	3	3	3	3	3	2
4	7	7	7	7	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3
5	8	8	8	8	7	7	7	7	7	6	6	6	6	6	5	5	5	5	5	5	4
6	9	9	9	9	8	8	8	8	8	7	7	7	7	7	6	6	6	6	6	6	5
7	10	10	10	10	9	9	9	9	9	8	8	8	8	8	7	7	7	7	7	7	6
8	11	11	11	11	10	10	10	10	10	9	9	9	9	9	8	8	8	8	8	8	7
9	12	12	12	12	11	11	11	11	11	10	10	10	10	10	9	9	9	9	9	9	8
10	13	13	13	13	12	12	12	12	12	11	11	11	11	11	10	10	10	10	10	10	9
11	14	14	14	14	13	13	13	13	13	12	12	12	12	12	11	11	11	11	11	11	10
12	15	15	15	15	14	14	14	14	14	13	13	13	13	13	12	12	12	12	12	12	11
13	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	13	13	13	13	13	12
14	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	14	13
15	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	15	14
16	19	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	16	15
17	20	20	20	20	19	19	19	19	19	18	18	18	18	18	17	17	17	17	17	17	16
18	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18	18	17

Notes: Education adjustment applying the following formula: $NSS_{A\&E\&S} = NSS_A - (\beta * [Education_{(years)} - 12]) - \gamma * Sex))$, where $\beta = 0.19405$; $\gamma = -1.37869$; and sex (woman) = 1. JLO = judgment of line orientation.

circumstances, the final score should be 18 or 2, respectively. It is important to stress that it would not be accurate to apply the computational formulae defined in this work to younger individuals due to the different impact of the demographic variables on the cognitive performance across the life span (*see* Lucas et al., 2005).

The general limitations of NEURONORMA norms have been discussed in a previous paper (Peña-Casanova et al., 2009), including the lack of epidemiological techniques of recruitment, stratification starting at age 50, and the limited representation of the extremely elderly. Despite its limitations, this study reflects the largest normative study to date for the neuropsychological performance of Spanish older subjects on selected test of the VOSP and JLO. The normative information provided here should prove useful for characterizing and interpreting individual test performances as well as comparing the scores from these tests with any other test with NEURONORMA norms. Correlation studies are needed to study the effect of other cognitive capacities on visual and spatial perception.

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Conflict of Interest

None declared.

Appendix

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