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Spanish Multicenter Normative Studies (NEURONORMA Project): Norms for Verbal Span, Visuospatial Span, Letter and Number Sequencing, Trail Making Test, and Symbol Digit Modalities Test

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Abstract

As part of the Spanish Multicenter Normative Studies (NEURONORMA project), we provide age- and education-adjusted norms for the following instruments: verbal span (digits), visuospatial span (Corsi's test), letter–number sequencing (WAIS-III), trail making test, and symbol digit modalities test. The sample consists of 354 participants who are cognitively normal, community-dwelling, and age ranging from 50 to 90 years. Tables are provided to convert raw scores to age-adjusted scaled scores. These were further converted into education-adjusted scaled scores by applying regression-based adjustments. The current norms should provide clinically useful data for evaluating elderly Spanish people. These data may be of considerable use for comparisons with other normative studies. Limitations of these normative data are mainly related to the techniques of recruitment and stratification employed.

Keywords: Attention; Problem-solving; Wechsler scales; Demography; Educational status; Reference values

Introduction

Attention is a very important aspect of neuropsychological assessment (Lezak, Howieson, & Loring, 2004), and attentional disorders affect a significant number of brain-injured patients (Strauss, Sherman, & Spreen, 2006). Many attentional tasks are

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multifactorial and overlap with other neuropsychological domains such as executive functions and memory, including components such as inhibition, switching capacity, or mental tracking (Strauss et al., 2006). Classification of these tasks is controversial and they may appear under different headings, for example, attention, working memory (WM), or executive tests. In fact, attention overlaps with the executive function of WM (Baddeley, 1986, 2003), so many existing tests of attention are a combination of attentional and executive functions. Attention is considered a complex system of interacting circuits that allow the filtering of relevant and irrelevant information within the context of internal and external stimuli.

A series of functional models of attention have been proposed (see Banich, 2004; Cohen, 1993). The standard model of WM (Baddeley, 1986) can no longer accommodate many empirical findings, and an alternative has been suggested: WM functions arise through the recruitment, via attention, of brain systems that have evolved to accomplish sensory-, representation-, and action-related functions (Postle, 2006). A recent computational and neural model, called PBWM (prefrontal cortex, basal ganglia WM model), relies on actively maintained representations in the prefrontal cortex which are dynamically updated/gated by the basal ganglia (Hazy, Frank, & O'Reilly, 2006). Functional connectivity argues for separate contributions of ventral and dorsal visual and auditory streams in WM (Buchsbaum, Olsen, Koch, & Berman, 2005).

In this paper, normative data are presented for the attention measures included in the Spanish Multicenter Normative Studies (NEURONORMA project) (Peña-Casanova et al. this issue). Some tests cover aspects of selective attention (i.e., WM) such as digit span or symbol substitution tasks, whereas others include capacities such as mental flexibility and motor speech, for example, the Trail Making Test. The Stroop Test (Golden, 1978; Stroop, 1935), which also measures attention, has also been studied, but is presented in another paper in this issue.

Verbal Span (Digit Span Forward and Backward)

This is both an attention and memory task. The digit span requires repeating sequences of digits of increasing length forward and then in reverse order. Both tests consist of seven pairs of random number sequences that the examiner reads aloud at the rate of one per second. Each test involves different mental activities and is affected differently by brain lesions (Banken, 1985; Kaplan, Fein, Morris, & Delis, 1991). The digit span test in the Wechsler tests is the format most commonly used to measure the span of immediate recall. Current Spanish norms are included in the WAIS-III and WMS-III manuals (Wechsler, 1987, 1997, 2004a, 2004b). Artiola, Hermosillo, Heaton, and Pardee (1999) included in the Spanish battery a digit span test adapted from the WAIS. The sample included 205 subjects from Spain, of whom only 33 were in the 55+ year range.

Forward Span

The digit forward span has a relatively restricted range and 89% of the subjects show spans within the 5–8 digit range (Kaplan et al., 1991). The normal range for forward digits is 6 ± 1 (Miller, 1956; Spitz, 1972), and education has an effect on the score (Ardila & Rosselli, 1989; Kaufman, McLean, & Reynolds, 1988). Age minimally affects forward span beyond the ages of 65 or 70 years (Hickman, Howieson, Dame, Sexton, & Kaye, 2000; Howieson, Holm, Kaye, Oken, & Howieson, 1993; Orsini, Grossi, Capitani, Laiacoma, Papagno, & Vallar, 1987). It is important to point out that differences in digit span forward performance between English and Spanish speakers are probably due to the greater number of syllables per digit in the Spanish language (Olazarán, Jacobs, & Stern, 1996).

Backward Span

This task involves mental tracking with verbal and visual processes (Larrabee & Kane, 1986) and includes a strong WM component. It is distinct from the more passive span measured by Digits Forward (Banken, 1985; Black, 1986). The normal raw score difference between forward digits and backward digits tends to range around 1 (from 0.59 to 2) (Black & Strub, 1978; Kaplan et al., 1991; Mueller & Overcast, 1976; Orsini et al., 1987). The normal span for backward digits is 4–5, and a score of 3 is considered borderline defective or defective depending on the educational level of the subject (Botwinick & Storand, 1974; Lezak et al., 2004). Scores typically decrease about one point beyond age 70, but not all older subjects get lower scores than younger ones (Canavan et al., 1989; Howieson et al., 1993).

Visuospatial Span (Corsi's Test)

It consists of nine cubes fastened in a random order in a board. Each time the examiner taps the blocks into a prearranged sequence, the patient must attempt to copy this pattern (Milner, 1971, 1972).

Block span is normally one to two points below digit span (Kaplan et al., 1991; Ruff, Evans, & Marshall, 1986) although in young controls a disparity of more than two points may be found (Smirni, Villardita, & Zappala, 1983). Education contributes significantly to performance on the test, and men tend to achieve slightly higher scores than women although this discrepancy is

virtually nonexistent for people with more than 12 years of education (Orsini, Chiacchio, Cinque, Cocchiara, Schiappa, & Grossi, 1986). Age effects appear after 60 years (Mittenberg, Seindenberg, O'Leary, & DiGiuglio, 1989). In a comparative study, English and Spanish speakers had similar scores on Visual Span (Olazarán et al., 1996).

The rate of age-related performance decline is equivalent for forward and backward measures of digit and spatial spans (Hester, Kinsella, & Ong, 2004).

Letter–Number Sequencing

Letter–Number Sequencing (LNS) is an addition to the standard measures of WM (digit span and visual span) included in the WAIS (WAIS-III, Wechsler, 1997). Patients are required to listen to an auditory presentation of alternating numbers and letters and then repeat back the numbers in ascending order, followed by the letters alphabetically. This test assesses processing speed and verbal and visual spatial WM (Crowe, 2000; Haut, Kuwabara, Leach, & Arias, 2000). Normative data show a moderate age effect (Crowe, 2000). Spanish norms of this test are included in the WMS-III Spanish edition (Wechsler, 2004a, 2004b).

Trail Making Test

Trail Making Test (TMT) assesses speed of visuomotor tracking, divided attention, mental flexibility, and motor function (Crowe, 1998). For historical aspects and versions of the test, see Strauss et al. (2006). The test has two parts: (A) drawing a line linking numbers in sequence and (B) drawing a line linking letters and numbers in sequence (Partington & Leiter, 1949; Reitan & Wolfson, 1993). The score derived for each trail is the number of seconds required to complete the task. Motor agility and speed make a strong contribution to successful performance in this test (Schear & Sato, 1989).

Normative data vary markedly according to the characteristics of the normative samples (Ashendorf et al., 2008; Giovagnioli et al., 1996; Lezak et al., 2004; Mitrushina, Boone, Razani, & D'Elia, 2005; Periáñez et al., 2007; Suokup et al., 1988; Strauss et al., 2006). Demographic effects such as age, education, ethnicity, and sex have been associated with TMT scores (Horton & Roberts, 2003). A recent meta-analysis study stressed that normative data from different countries and cultures are not equivalent, a fact that might lead to serious diagnostic errors (Fernández & Marcopulos, 2008).

Performance on TMT is affected by age: increased age is related to poorer test scores (Ernst, Warner, Townes, Peel, & Preston, 1987; Periáñez et al., 2007; Rasmusson, Zonderman, Kawas, & Resnick, 1998; Salthouse et al., 2000; Stuss, Stethem, & Poirier, 1987; Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000). Lower levels of education are associated with the poorest test scores (Bornstein, 1985; Bornstein & Suga, 1988; Ernst, 1987; Stuss, Stethem, Hugenholtz, & Richard, 1989). Sex has little impact on performance in adults (Hester, Kinsella, Ong, & McGregor, 2005; Lucas et al., 2005; Tombaugh, 2004) although women may perform slower than men in part B (Bornstein, 1985; Ernst, 1987).

The TMT was included in the MOANS (Steinberg, Bieliauskas, Smith, & Ivnik, 2005) and MOAANS (Lucas et al., 2005) projects. Spanish norms are available (Del Ser et al., 2004; Periáñez et al., 2007). The study of Periáñez and colleagues (2007) consisted of 223 healthy control subjects: 69 were in the 16–24 year range, 89 were in the 25–54 year range, and 65 were in the 55–80 year range. The study of Del Ser and colleagues (2004) examined a population sample aged more than 70 years.

Spanish speakers commonly use two versions of the alphabet, one that includes the sound/grapheme "Ch" between C and D and another that goes directly from C to D. Recently, versions of the TMT part B have been created and compared (Cherner et al., 2008). The findings of the comparison suggest that both versions are equivalent and can be administered to Spanish speakers without affecting comparability.

Symbol Digit Modalities Test

Symbol Digit Modalities Test (SDMT) (Smith, 1982 [First Edition, 1973]) measures divided attention, visual scanning, visual tracking, perceptual speed, motor speed, and memory (Shum, McFarland, & Bain, 1990). A coding key is presented, consisting of nine meaningless geometric designs each paired with a number. The subject is required to scan the key and write down the number corresponding to each design as rapidly as possible in 90 seconds. There is a practice period (10 boxes). The number of correct responses is recorded. The maximum score is 110.

A series of normative studies have been published (Lezak et al., 2004; Mitrushina et al., 2005; Smith, 1982 [Revised Manual]; Strauss et al., 2006; Sheridan et al., 2006) including a Spanish version (Smith, 2002). The Spanish normative study consists of 1,054 adult subjects from 18 to 85 years old. Norms are presented for six age groups and only two groups of education (basic and superior).

Manual speed and agility contribute significantly to SDMT performance (Schear & Sato, 1989). SDMT scores decline with age (see Strauss et al., 2006 for a review). This decline probably reflects changes in the speed of both motor response and

information processing (Gilmore, Royer, & Gruhn, 1983a, 1983b) and in memory (Joy, Kaplan, & Fein, 2004). Performance improves with increasing education (Richardson & Marottoli, 1996). Education- and age-corrected norms for people older than 75 years have been developed (Richardson & Marottoli, 1996). Sex differences have not always been found and appear to be of insufficient magnitude to create separate gender-based norms (Gilmore et al., 1983a, 1983b), although this finding has not always been consistent (Jorm, Anstey, & Christensen, 2004).

Materials and Methods

Research Participants

Recruitment procedures, socio-demographic characteristics and participant characteristics of the entire NEURONORMA sample have been reported in a previous paper (*see* Peña-Casanova et al., 2009). Due to logistic organization, not all the participants were administered one or more neuropsychological measures. Data from all completed tests were included in the normative studies, leading to minor sample size variations among tests. The distribution of demographic variables by test is presented in Table 1.

Neuropsychological Measures

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

Verbal Span

The two parts of the digit span test (forward and backward) in the Spanish version (Peña-Casanova, 2005) were administered following standard procedures as indicated in the WAIS-III manual (Wechsler, 1997). The range of raw scores (last series) is the following: forward digits 0–9; backward digits 0–8.

Table 1. Sample size by demographics and test

	Verbal Span		Visuospatial Span		LNS		Trail Making Test				Symbol-Digit Modalities Test	
							Part A		Part B			
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Age Group												
50–56	76	21.47	76	21.78	74	22.16	76	21.71	75	22.94	76	21.97
57–59	51	14.41	51	14.61	51	15.27	51	14.57	49	14.98	51	14.74
60–62	34	9.60	34	9.74	34	10.18	34	9.71	30	9.17	34	9.83
63–65	19	5.37	18	5.16	16	4.79	18	5.14	16	4.89	17	4.91
66–68	26	7.34	26	7.45	24	7.19	25	7.14	24	7.34	26	7.51
69–71	50	14.12	48	13.75	46	13.77	49	14.00	49	14.98	49	14.16
72–74	33	9.32	32	9.17	30	8.98	33	9.43	29	8.87	32	9.25
75–77	31	8.76	31	8.88	29	8.68	31	8.86	26	7.95	30	8.67
78–80	21	5.93	21	6.02	20	5.99	21	6.00	19	5.81	21	6.07
>80	13	3.67	12	3.44	10	2.99	12	3.43	10	3.06	10	2.89
Education (Years)												
≤5	76	21.47	73	20.92	63	18.86	72	20.57	57	17.43	69	19.94
6–7	26	7.34	25	7.16	24	7.19	25	7.14	22	6.73	24	6.94
8–9	67	18.93	66	18.91	64	19.16	67	19.14	62	18.96	67	19.36
10–11	41	11.58	41	11.75	40	11.98	40	11.43	40	12.23	40	11.56
12–13	35	9.89	36	10.32	35	10.48	36	10.29	36	11.01	36	10.40
14–15	33	9.32	33	9.46	33	9.88	34	9.71	34	10.40	34	9.83
≥16	76	21.47	75	21.49	75	22.46	76	21.71	76	23.24	76	21.97
Gender												
Male	143	40.40	140	40.11	138	41.32	141	40.29	138	42.20	140	40.46
Female	211	59.60	209	59.89	196	58.68	209	59.71	189	57.80	206	59.54
Total Sample (*n*)	354		349		334		350		327		346	

Notes: *N* = number (count); LNS = letter–number sequencing.

Visuospatial Span

The two parts of the visual memory span (tapping forward and tapping backward) were administered following administration procedures as indicated in the WMS-R-NI manual (Corsi's Test, from the WAIS-R-NI, Kaplan et al., 1991). This version requires two administrations at each level. The longest span was recorded (last item score) and the global score as well (sum of all administrations). The range scores for forward and backward formats are the following: last item (longest score) 0–8; raw score (global score) 0–16.

Letter–Number Sequencing

Standard administration procedures were followed as indicated in the test manual (WAIS-III, Wechsler, 1997). The range of the possible raw scores is from 0 to 21. The last item (the longest score) has a maximum of 7.

Trail Making Test

Parts A and B were administered following the procedures described by Reitan and Wolfson (1985). Following these standard procedures, "Ch" was not included. We allowed unlimited time for participants to complete the test. Score was recorded as the time in seconds to complete each of the two parts of the test.

Symbol Digit Modalities Test

Standard administration procedures were followed as indicated in the test manual (Smith, 1973). In all cases, 10 sample practice boxes were administered prior to the presentation of the actual 110 test items. The score of the test is the number of correct substitutions in a 90-second interval. The maximum score is 110.

Statistical Analysis

The same statistical procedures as those used in other NEURONORMA normative studies were applied to all measures (*see* Peña-Casanova et al., 2009). Briefly, the primary steps of this process were: (a) use of midpoint age intervals (Pauker, 1988) to maximize the information available at each age and measure. Each midpoint age group provides norms for individuals of that age, ± 1 year; (b) coefficients of correlation (r) and determination (r^2) of all raw scores with age, years of education, and sex were determined; (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). For each age range, a cumulative frequency distribution of the raw scores was generated. Raw scores were assigned percentile ranks in function of their place within a distribution. Subsequently, percentile ranks were converted into scaled scores (from 2 to 18) based on percentile ranges. From these data, normative tables (NSS_A) were created. This transformation of raw scores to NSS_A produced a normalized distribution (mean $=10$; SD $=3$) on which linear regressions could be applied; (d) years of education were modeled using the following equation: $NSS_A = k + (\beta * \text{Educ})$. The regression coefficient (β) from this analysis was taken as the basis for education adjustments. A linear regression was employed to derive age- and education-adjusted scaled scores. The following formula outlined by Mungas, Marshall, Weldon, Haan, and Reed (1996) was employed:

$$NSS_{A\&E} = NSS_A - (\beta^* \, [\text{Educ} - 12]).$$

The obtained value was truncated to the next lower integer (e.g., 10.75 would be truncated to 10).

Results

Age distribution of the sample made it possible to calculate norms for 10 midpoint age groups. The sample sizes resulting from mid-point age intervals are shown in each normative table.

Effects of age, education, and sex (correlations and shared variances) on raw scores are presented in Table 2. Age and education accounted significantly for raw score variance for all measures. Sex differences were minimal (2–3%) or not observed, indicating no need to control this demographic variable.

Age-adjusted NEURONORMA scaled scores (NSS_A), percentile ranks, ranges of ages contributing to each normative group, and the number of participants contributing to each test normative estimate are shown in Tables 3–12. To use these data, select the appropriate normative table corresponding to the patient's age, find the appropriate test heading, find the patient's raw score, and subsequently refer to the corresponding NSS_A and associated percentile rank (left part of the table).

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

Neuropsychological Measure	Age (years)		Education (years)		Sex	
	r	r^2	r	r^2	r	r^2
Verbal Span						
Forward	−0.22285	0.04966	0.48146	0.23180	−0.14623	0.02138
Backwards	−0.26298	0.06916	0.52124	0.27169	−0.18675	0.03488
Visuospatial Span						
Last Item Forward	−0.21009	0.04414	0.25412	0.06458	−0.12325	0.01519
Forward Raw Score	−0.24247	0.05879	0.33336	0.11113	−0.14558	0.02119
Last Item Backwards	−0.30296	0.09178	0.42161	0.17775	−0.14292	0.02043
Backwards Raw Score	−0.31042	0.09636	0.46298	0.21435	−0.12384	0.01534
Letter Number Sequencing						
Last Item	−0.34826	0.12129	0.51502	0.26525	−0.18212	0.03317
Raw Score	−0.39787	0.15830	0.59019	0.34832	−0.15682	0.02459
Trail Making Test						
Part A	0.36752	0.13507	−0.47575	0.22634	0.07414	0.00550
Part B	0.33183	0.11011	−0.51500	0.26523	0.09482	0.00899
Symbol Digit Modalities Test						
Total Score	−0.47709	0.22761	0.66646	0.44417	−0.04979	0.00248

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤3	0	≤2	≤1	≤1	≤1	≤2	0	≥121	≥480	≤5
3	1	—	2	—	—	—	—	3	1	118–120	406–479	6
4	2	—	—	3	—	2	—	—	—	102–117	381–405	7–12
5	3–5	4	—	4	2	3	—	4	—	81–101	223–380	13–17
6	6–10	—	—	—	—	—	2	5	2	68–80	178–222	18–21
7	11–18	—	—	5	—	4	—	6	—	59–67	138–177	22–27
8	19–28	—	—	—	—	5	—	7	—	54–58	123–137	28–33
9	29–40	5	3	—	3	—	—	8	3	47–53	108–122	34–36
10	41–59>	—	4	6–7	4	6	3	9–10	—	36–46	80–107	37–48
11	60–71	6	—	8	—	7	4	—	4	34–35	71–79	49–52
12	72–81	—	—	—	—	—	—	11	—	29–33	64–70	53–54
13	82–89	—	5	9	5	8	—	12	—	26–28	55–63	55–56
14	90–94	7	—	10	—	—	5	—	5	25	51–54	57–59
15	95–97	8	6	11	6	9	—	13	—	24	45–50	60–63
16	98	—	—	—	—	10	—	14	—	23	43–44	64–67
17	99	—	—	12	7	—	—	15	6	18–22	42	68–69
18	>99	9	7	≥13	8	≥11	≥6	≥16	7	≤17	≤41	≥70
Sample Size		136		136				135		137	133	137

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

Correlation (r) and shared variances (r^2) for age and education with NSS_A are presented for all neuropsychological measures in Table 13. As expected, the normative adjustments eliminated the shared variance for all tests. Education, however, continues to account for up to 38% of shared variances with NSS_A.

The transformation of raw scores to NSS_A produced a normalized distribution on which linear regressions could be applied. Linear regressions resulted in computational formulae to calculate $NSS_{A\&E}$ (Table 14). From these data we have constructed $NSS_{A\&E}$ adjustment tables (Tables 15–25) to help the clinician make the necessary adjustments. To use the tables select the appropriate column corresponding to the patient's years of education, find the patient's NSS_A, and subsequently refer to the corresponding $NSS_{A\&E}$. When these formulae were applied to the normative sample, the shared variances between $NSS_{A\&E}$ and years of education fell to <1%.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤3	0	≤2	≤1	≤1	0	≤2	0	≥121	≥406	≤5
3	1	—	—	—	—	—	—	—	1	118–120	383–405	6
4	2	—	—	—	—	—	—	3	—	110–117	381–382	7–11
5	3–5	—	2	3	2	2	1	—	—	87–109	231–380	12–16
6	6–10	4	—	4	—	3	—	4	—	73–86	197–230	17–19
7	11–18	—	—	—	—	4	2	5	2	61–72	151–196	20–24
8	19–28	—	—	5	—	—	—	6	—	56–60	129–150	25–30
9	29–40	—	3	—	3	5	—	7–8	3	50–55	114–128	31–34
10	41–59	5	4	6–7	4	—	3	9	—	41–49	89–113	35–44
11	60–71	—	—	8	—	6	—	10	4	35–40	73–88	45–49
12	72–81	6	—	9	—	7	4	11	—	30–34	66–72	50–52
13	82–89	—	5	—	5	8	—	—	—	26–29	56–65	53–55
14	90–94	7	—	10	—	9	5	12	5	25	53–55	56–57
15	95–97	—	6	—	6	—	—	13	—	24	45–52	58–59
16	98	8	—	—	—	—	—	—	—	23	—	60–63
17	99	—	—	11	7	10	—	14	—	18–22	42–44	64–67
18	>99	9	7	≥12	8	≥11	≥6	≥15	≥6	≤17	≤41	≥68
Sample Size		133		133				131		133	125	132

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤3	0	≤2	≤1	≤1	0	≤2	0	≥131	≥406	≤5
3	1	—	—	—	—	—	—	—	1	121–130	383–405	6
4	2	—	—	—	—	—	—	—	—	—	381–382	7–11
5	3–5	—	2	3	2	2	1	3	—	103–119	253–380	12–15
6	6–10	—	—	4	—	3	—	4	—	85–102	206–252	16–18
7	11–18	4	—	—	—	—	2	5	2	68–84	161–205	19–21
8	19–28	—	—	5	—	4	—	6	—	60–67	135–160	22–28
9	29–40	—	3	—	3	5	—	7	—	55–59	119–134	29–33
10	41–59	5	—	6–7	4	—	3	8	3	42–54	101–118	34–37
11	60–71	—	4	—	—	6	—	9	4	36–41	79–100	38–46
12	72–81	6	—	8	—	7	4	10–11	—	32–35	71–78	47–49
13	82–89	—	—	—	5	8	—	—	—	27–31	61–70	50–53
14	90–94	7	5	9	—	—	5	12	5	26	53–61	54–56
15	95–97	—	6	10	6	9	—	—	—	25	49–52	57–58
16	98	8	—	—	—	—	—	13	—	24	48	59
17	99	—	—	11	7	10	—	14	6	—	47	60–63
18	>99	9	7	≥12	8	≥12	≥6	≥15	7	≤23	≤46	≥64
Sample Size		125		125				122		123	116	123

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

Discussion

In this study, we present normative data on age and education for the attention measures included in the NEURONORMA project. These data were derived from a well-characterized Spanish sample of 354 participants who were cognitively normal, community-dwelling, and ranging from 50 to 90 years.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤3	0	≤2	≤1	≤1	0	≤2	0	≥132	≥481	≤6
3	1	—	—	—	—	—	—	—	1	121–131	449–480	—
4	2	—	—	—	—	—	—	—	—	112–120	402–448	7–11
5	3–5	—	2	3	2	2	1	3	—	104–111	301–401	12–14
6	6–10	—	—	4	—	—	—	—	—	87–103	222–300	15–16
7	11–18	4	—	—	—	3	2	4	—	75–86	191–221	17–20
8	19–28	—	—	5	—	4	—	5	2	64–74	145–190	21–24
9	29–40	—	—	—	3	5	—	6	—	59–63	131–144	25–30
10	41–59	5	3	6	—	—	3	7–8	3	47–58	101–130	31–36
11	60–71	—	4	7	4	—	—	—	—	38–46	82–100	37–40
12	72–81	—	—	8	—	6	4	9–10	4	33–37	70–81	41–46
13	82–89	6	—	—	5	7–8	—	11	—	30–32	64–69	47–50
14	90–94	—	5	9	—	9	5	12	—	27–29	56–63	51–54
15	95–97	7	—	—	—	—	—	—	5	25–26	48–55	55
16	98	8	—	—	—	10	—	—	—	24	43–47	56
17	99	—	—	10	6	11	—	13	6	—	42	57
18	>99	9	6	≥11	≥7	≥12	≥6	≥14	7	≤23	≤41	≥58
Sample Size		109		109				102		106	99	106

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤2	0	≤2	≤1	≤1	0	≤2	0	≥138	≥402	≤8
3	1	—	—	—	—	—	—	—	1	132–137	383–401	—
4	2	3	—	—	—	2	—	—	—	125–131	318–382	9
5	3–5	—	2	3	2	3	1	3	—	104–124	267–317	10–12
6	6–10	—	—	4	—	4	—	—	—	87–103	222–266	13–15
7	11–18	—	—	—	—	—	2	4	—	74–86	193–221	16–19
8	19–28	4	—	5	3	5	—	5	2	63–73	157–192	20–24
9	29–40	—	3	6	—	—	—	6	—	58–62	137–158	25–27
10	41–59	5	—	7	4	6	—	7–8	3	49–57	106–136	28–34
11	60–71	—	4	—	—	—	3	—	—	44–48	92–105	35–39
12	72–81	—	—	8	—	7	4	—	4	37–43	79–91	40–44
13	82–89	6	—	—	—	8	—	9	—	33–36	72–78	45–48
14	90–94	—	5	9	5	9	—	10	—	31–32	68–71	49–50
15	95–97	7	—	—	—	—	5	11	5	25–30	60–67	51–56
16	98	—	—	—	—	—	—	12	—	24	48–59	57
17	99	8	—	—	6	10	6	—	6	—	43–47	58
18	>99	9	6	≥10	≥7	≥11	≥7	≥14	7	≤23	≤42	≥59
Sample Size		124		124				114		121	116	121

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

Data from Table 2 show that education had more effect than age on raw scores of all tests. The effect of age for the raw score variance was ≤9% for Verbal Span (VS) and Visuospatial Span (VSS). The effect of age was higher for more complex tests (LNS, TMT, SDMT) and especially for SDMT (23% [rounded]). Education accounted significantly for the raw score variance of all measures and particularly, again, for SDMT (44%). The effect of sex was very small (≤3%) or practically absent (<1%) in all tests.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤2	0	≤2	≤1	≤1	0	0	0	≥171	≥501	≤8
3	1	—	—	—	—	—	—	—	—	159–170	449–500	—
4	2	3	—	—	2	—	—	—	1	158	421–448	—
5	3–5	—	2	3	—	2	1	1–3	—	121–157	309–420	9–11
6	6–10	—	—	4	—	3	—	—	—	110–120	241–308	12–14
7	11–18	—	—	—	—	4	2	4	—	79–109	194–240	15–19
8	19–28	4	—	5	—	—	—	5	—	68–78	168–193	20–22
9	29–40	—	—	—	3	5	—	6	2	60–67	139–167	23–26
10	41–59	5	3	6	—	—	—	7–8	3	51–59	114–138	27–31
11	60–71	—	—	7	4	—	3	—	—	45–50	97–113	32–35
12	72–81	—	4	8	—	6	—	9	—	38–44	82–96	36–40
13	82–89	6	—	—	—	7	4	—	4	34–37	73–81	41–47
14	90–94	—	5	9	—	8	—	10	—	32–33	67–72	48–50
15	95–97	7	—	—	5	9	5	11–12	5	28–31	61–66	51–55
16	98	—	—	—	—	—	—	—	—	25–27	—	—
17	99	8	6	—	—	10	6	13	6	—	43–60	56–58
18	>99	9	7	≥10	≥6	≥11	≥7	≥14	7	≤24	≤42	≥59
Sample Size		129		129				120		124	120	126

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤2	0	≤2	≤1	≤1	0	0	0	≥171	≥501	≤8
3	1	—	—	—	—	—	—	—	—	161–170	462–500	—
4	2	3	—	—	—	—	—	—	—	160	449–461	—
5	3–5	—	2	3	2	2	1	1–2	1	138–159	337–448	9
6	6–10	—	—	4	—	3	—	3	—	110–137	274–336	10–13
7	11–18	4	—	—	—	—	2	4	—	85–109	214–273	14–17
8	19–28	—	—	5	—	4	—	5	—	73–84	191–213	18–21
9	29–40	—	—	—	3	—	—	6	2	64–72	149–190	22–24
10	41–59	5	3	6	—	5	—	7	3	54–63	116–148	25–30
11	60–71	—	—	7	4	—	3	8	—	47–53	105–115	31–33
12	72–81	—	4	8	—	6	—	9	—	43–46	92–104	34–38
13	82–89	6	—	—	—	7	4	—	4	36–42	76–91	39–42
14	90–94	—	5	9	—	8	—	10	—	34–35	69–75	46–50
15	95–97	7	—	—	5	9	5	11	—	31–33	64–68	51–55
16	98	—	—	—	—	10	—	12	—	30	61–63	—
17	99	8	6	—	—	—	6	13	5	29	—	56–58
18	>99	9	7	≥10	≥6	≥11	≥7	≥14	≥6	≤28	≤60	≥59
Sample Size		129		129				119		127	117	117

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

We chose to use the same methods of analysis that have been used in normative studies at the Mayo Clinic (e.g., Ivnik et al., 1992; Lucas et al., 2005). Although some measures (e.g., the digit span) are psychometrically different to, for example, the TMT or the SDMT, we decided to maintain the same model of analysis (see below).

Table 10. Age-adjusted NEURONORMA scores (NSS_A) for age 75–77 (age range for norms = 71–81)

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤2	0	≤2	≤1	≤1	0	0	0	≥171	≥540	≤8
3	1	3	—	—	—	—	—	—	—	161–170	501–539	—
4	2	—	—	—	—	—	—	1	—	160	462–500	—
5	3–5	—	—	3	2	2	1	—	—	138–159	365–461	9–10
6	6–10	—	2	4	—	—	—	2	1	110–137	281–364	11–12
7	11–18	4	—	—	—	3	—	3–4	—	88–109	221–280	13–15
8	19–28	—	—	5	—	—	2	—	—	78–87	194–220	16–19
9	29–40	—	—	—	3	4	—	5	2	68–77	160–193	20–22
10	41–59	5	3	6	—	5	—	6–7	—	57–67	121–159	23–28
11	60–71	—	—	—	—	—	3	8	3	48–56	107–120	29–31
12	72–81	—	4	7	4	6	—	9	—	45–47	96–106	32–34
13	82–89	6	—	8	—	—	—	10	4	38–44	83–95	35–41
14	90–94	—	5	—	—	7	4	11	—	36–37	75–82	42–49
15	95–97	—	—	9	—	9	—	12	—	34–35	64–74	50–55
16	98	7	—	—	5	—	5	13	5	—	61–63	—
17	99	8	6	—	—	—	6	14	—	30–33	60	58
18	>99	9	7	≥10	≥6	≥10	≥7	≥15	≥6	≤29	≤59	≥59
Sample Size		103		103				94		103	91	101

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤2	0	≤1	≤1	≤1	0	0	0	≥171	≥539	≤7
3	1	3	—	2	—	—	—	1	—	170	462–538	8
4	2	—	—	—	—	—	—	—	—	161–169	429–461	—
5	3–5	—	—	3	—	—	—	—	—	146–160	353–428	9–10
6	6–10	—	2	4	2	2	1	2	1	106–145	317–352	11
7	11–18	4	—	—	—	3	—	3–4	—	88–105	241–316	12–14
8	19–28	—	—	5	—	—	2	—	—	80–87	215–240	15–19
9	29–40	—	—	—	3	—	—	5	2	74–79	191–214	20–21
10	41–59	5	3	6	—	4–5	—	6–7	—	63–73	142–190	22–26
11	60–71	—	—	—	—	—	3	—	—	55–62	120–141	27–29
12	72–81	—	4	7	4	—	—	8	3	43–54	107–119	30–33
13	82–89	6	—	8	—	6	—	9	4	42	84–106	34–35
14	90–94	—	5	9	—	—	—	10	—	36–41	83	36–40
15	95–97	—	—	—	5	7	4	11	—	31–35	80–82	41–42
16	98	—	—	—	—	—	—	12	—	—	64–79	43–46
17	99	7	6	10	—	8	—	—	—	30	63	—
18	>99	8	7	≥11	≥6	≥9	≥5	≥13	≥5	≤29	≤62	≥47
Sample Size		67		67				61		67	58	68

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

VS and VSS

Our results show that age and education were associated with verbal and visuospatial span raw score. Tables 3–12 show a highly significant distribution of NSS_A scores, especially considering that the critical NSS_A 6 has an associated percentile rank of 6–10. In fact, Lezak et al. (2004), although recognizing the effect of age and education, suggested that "spans of 6 or better are well within normal limits, a span of 5 may be marginal to normal limits, a span of 4 is definitely borderline, and 3 is

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

Scaled Score	Percentile Range	Digit Span		Corsi Blocks				LNS		Trail Making Test		SDMT
		Forward	Backward	Forward		Backward		Raw Score	Last Item Score	Part A	Part B	
				Raw Score	Last Item Score	Raw Score	Last Item Score					
2	<1	≤3	0	≤1	≤1	0	0	0	0	≥161	≥461	≤9
3	1	—	—	—	—	—	—	—	—	—	—	—
4	2	—	—	2	—	—	—	1	—	160	429–460	10
5	3–5	—	—	—	—	—	—	—	—	106–159	368–428	11
6	6–10	—	—	3	2	2	1	2	1	92–105	353–367	12
7	11–18	—	2	4	—	—	—	3	—	88–91	299–352	13–15
8	19–28	4	—	5	—	—	—	4	—	81–87	236–298	16–18
9	29–40	—	—	—	3	3	2	5	2	75–80	211–235	19–20
10	41–59	—	3	6	—	4	—	6	—	65–74	164–210	21–24
11	60–71	5	—	—	4	5	—	7	—	58–64	121–163	25–27
12	72–81	—	4	7	—	6	3	8	3	43–57	115–120	28–30
13	82–89	6	—	8	—	—	—	9–10	—	42	99–114	31–33
14	90–94	—	5	—	—	—	—	—	4	37–41	84–98	34–40
15	95–97	—	—	9	5	7	4	11–12	—	25–36	81–83	41–42
16	98	—	—	10	—	—	—	—	—	24	80	—
17	99	—	—	—	—	—	—	—	—	—	—	—
18	>99	7	6	≥11	≥6	≥8	≥5	≥13	≥5	≤23	≤79	≥43
Sample Size		43		43				38		48	37	40

Notes: LNS = letter–number sequencing; SDMT = symbol digit modalities test.

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

Neuropsychological Measure	Age (years)		Education (years)	
	r	r^2	r	r^2
Verbal Span				
Forward	0.00518	0.00003	0.42410	0.17986
Backwards	−0.02659	0.00071	0.44477	0.19782
Visuospatial Span				
Last Item Forward	−0.00218	0.00000	0.21603	0.04667
Forward Raw Score	−0.04978	0.00248	0.28257	0.07985
Last Item Backwards	−0.02284	0.00052	0.34355	0.11803
Backwards Raw Score	−0.00671	0.00005	0.38367	0.14720
Letter Number Sequencing				
Last Item	−0.01629	0.00027	0.46607	0.21722
Raw Score	−0.04192	0.00176	0.54233	0.29412
Trail Making Test				
Part A	0.05760	0.00332	−0.42860	0.18370
Part B	0.05578	0.00311	−0.52234	0.27284
Symbol Digit Modalities Test				
Total Score	−0.05487	0.00301	0.61922	0.38343

defective" (p. 353). Our results tend to confirm this statement, but are more objective because we introduced adjustments for age and education. Also, due to the NEURONORMA adjustments, it is possible to go beyond the statement that "*a* [digit] *span of 4 is definitely borderline.*" Tables 3–12 show that a span of 4 is only defective in younger subjects (50–59 years old) because it is associated with an NSS_A of 5 for 50–56 years, and with an NSS_A of 6 for 57–59 years. Furthermore, Table 15 ($NSS_{A\&E}$), shows that only in cases of practically no education (0–2 years) for 50–56 years the adjusted final $NSS_{A\&E}$ is 7. When years of education increase $NSS_{A\&E}$ goes down. The same effect is observed for age 57–59 years, but for cases of no/minimal education (0–2 years) the resulting NSS_A of 6 is adjusted to an $NSS_{A\&E}$ of 8 (normal). The same subject with 3–7 years of education would receive a $NSS_{A\&E}$ of 7, and with a range of 17–20 years of education would receive an $NSS_{A\&E}$ of 5 (clearly defective).

Table 14. Computational formulae for age and education adjusted NEURONORMA scores

Neuropsychological Measure	β
Verbal Span	
Forward	0.21327
Backwards	0.21298
Visuospatial Span	
Last Item Forward	0.11357
Forward Raw Score	0.14886
Last Item Backwards	0.17787
Backwards Raw Score	0.20213
Letter Number Sequencing	
Last Item	0.24927
Raw Score	0.28804
Trail Making Test	
Part A	−0.21832
Part B	−0.27320
Symbol Digit Modalities Test	
Total Score	0.32136

Notes: $NSS_{A\&E} = NSS_A - (\beta^*(Educ - 12))$.

Table 15. Verbal span: Digits forward

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

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta * (Education_{(years)} - 12))$, where $\beta = 0.21327$.

As expected, our study shows that the raw score difference between forward and backward digits tends to range from 1 to 2 (see NSS_A 10 in Tables 5–12). Normal raw scores for backward digits are 4 to 5, and a score of 3 may be considered borderline. In fact, a raw score of 2 has an associated NSS_A of 5 in all tables, except in tables for subjects aged 75+ years. For subjects aged 75–80 years the associated NSS_A is 6, and for subjects aged 80+ years the associated NSS_A is 7. These data show clearly the effect of age (see Canavan et al., 1989; Howieson et al., 1993). Despite of high prevalence of pre-clinical dementia in the elderly, we consider that the minimal education level of oldest groups could explain the low raw scores obtained in backward digits. In this case, education adjustments of NSS_A scores are fundamental because they add one or two points at people with few years of education (see Table 16). The final Scaled Score obtained after those adjustments are much more comparable to the other authors presented (see Botwinick & Storand, 1974; Lezak et al., 2004).

Our results also confirm that block span is normally one to two points below digit span and that education contributes significantly to performance on the test. Although we offer normative tables for block total score (sum of all administrations [raw

Table 16. Verbal span: Digits backward

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

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = 0.21298$.

Table 17. Visuospatial span forward: Last item

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	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
3	4	4	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
4	5	5	5	5	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3
5	6	6	6	6	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4
6	7	7	7	7	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5
7	8	8	8	8	7	7	7	7	7	7	7	7	7	6	6	6	6	6	6	6	6
8	9	9	9	9	8	8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	7
9	10	10	10	10	9	9	9	9	9	9	9	9	9	8	8	8	8	8	8	8	8
10	11	11	11	11	10	10	10	10	10	10	10	10	10	9	9	9	9	9	9	9	9
11	12	12	12	12	11	11	11	11	11	11	11	11	11	10	10	10	10	10	10	10	10
12	13	13	13	13	12	12	12	12	12	12	12	12	12	11	11	11	11	11	11	11	11
13	14	14	14	14	13	13	13	13	13	13	13	13	13	12	12	12	12	12	12	12	12
14	15	15	15	15	14	14	14	14	14	14	14	14	14	13	13	13	13	13	13	13	13
15	16	16	16	16	15	15	15	15	15	15	15	15	15	14	14	14	14	14	14	14	14
16	17	17	17	17	16	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	15
17	18	18	18	18	17	17	17	17	17	17	17	17	17	16	16	16	16	16	16	16	16
18	19	19	19	19	18	18	18	18	18	18	18	18	18	17	17	17	17	17	17	17	17

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = 0.11357$.

score]) we agree with Lezak and colleagues (2004) that for neuropsychological purposes—as in the case of digits—"spans forward and reversed are meaningful pieces of information that require no further elaboration for interpretation" (p. 352).

Letter–Number Sequencing

Due to significant differences in samples, methods, and age ranges, it is difficult to compare our data with norms published in the Spanish WMS-III manual (2004). It is noteworthy that, despite this problem, there is a practical equivalence of our Table 5 (age range 56–66, $n = 122$) with table D4 of the WMS-III manual (age range 55–65, $n = 122$). Furthermore, a raw score of 4 is associated with a scaled score of 6 (cut-off score, percentile range 6–10) in both sets of norms. For older subjects (NEURONORMA Tables 11–12 and WMS-III manual Table D-6) this fact has not been observed. A major difference

Table 18. Visuospatial Span Forward: Raw score

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	3	2	2	2	2	2	2	2	1	1	1	1	1	1	0	0
3	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2	1	1
4	5	5	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3	2	2
5	6	6	6	6	6	6	5	5	5	5	5	5	5	4	4	4	4	4	4	3	3
6	7	7	7	7	7	7	6	6	6	6	6	6	6	5	5	5	5	5	5	4	4
7	8	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6	6	6	6	5	5
8	9	9	9	9	9	9	8	8	8	8	8	8	8	7	7	7	7	7	7	6	6
9	10	10	10	10	10	10	9	9	9	9	9	9	9	8	8	8	8	8	8	7	7
10	11	11	11	11	11	11	10	10	10	10	10	10	10	9	9	9	9	9	9	8	8
11	12	12	12	12	12	12	11	11	11	11	11	11	11	10	10	10	10	10	10	9	9
12	13	13	13	13	13	13	12	12	12	12	12	12	12	11	11	11	11	11	11	10	10
13	14	14	14	14	14	14	13	13	13	13	13	13	13	12	12	12	12	12	12	11	11
14	15	15	15	15	15	15	14	14	14	14	14	14	14	13	13	13	13	13	13	12	12
15	16	16	16	16	16	16	15	15	15	15	15	15	15	14	14	14	14	14	14	13	13
16	17	17	17	17	17	17	16	16	16	16	16	16	16	15	15	15	15	15	15	14	14
17	18	18	18	18	18	18	17	17	17	17	17	17	17	16	16	16	16	16	16	15	15
18	19	19	19	19	19	19	18	18	18	18	18	18	18	17	17	17	17	17	17	16	16

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = 0.14886$.

Table 19. Visuospatial span backward: Last item

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 $\beta = 0.17787$.

to WMS-III norms is that NEURONORMA norms permit adjustments for years of education. This is a very important point in helping clinicians to arrive at clinically meaningful interpretation of scores (see Ryan, Sattler, & Lopez, 2000).

Finally, it is worth commenting that when comparing VS and VSS with LNS data, the effects of age and education are different and this fact is reproduced in our norms. This result probably reflects differences in the overlap of these tasks with other neuropsychological domains (see Crowe, 2000; Emery, Myerson, & Hale, 2007; Myerson, Emery, White, & Hale, 2003).

Trail Making Test

Demographic variables, age, and education affected the score of the TMT, but sex was found to be unrelated to scores in this normal sample. Thus our data are in accordance with previous studies (e.g., Bornstein, 1985; Bornstein & Suga, 1988; Ernst

Table 20. Visuospatial Span Backward: Raw score

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

Notes: Education adjustment applying the following formula: $NSS_{A\&E}=NSS_A-(\beta^*(Education_{(years)}-12))$, where $\beta = 0.20213$.

Table 21. Letter–number sequencing: Last item

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

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = 0.24927$.

et al., 1987; Hester et al., 2005; Lucas et al., 2005; Rasmusson et al., 1998; Salthouse, et al., 2000; Stuss et al., 1987; Tombaugh, 2004; Wecker et al., 2000). Age accounts for 13% and 11% of the variance of raw score for Trails A and B, respectively, whereas education accounts for 22% and 26%, respectively. As we allowed unlimited time for participants to complete the test our norms do not show the floor effect observed by Lucas and colleagues (2005) in Part B. Comparison of our Part A scaled score of 10 (Tables 4–11) with MOAANS data (Lucas et al., 2005 [Tables 4–10]) shows practically the same results. Furthermore, scaled scores 7–6 are in very similar range of raw score in both norms.

Due to significant differences in samples and methods, it is difficult to compare our data with other Spanish language studies (e.g., Del Ser et al. 2004; Periáñez et al., 2007).

Table 22. Letter–number sequencing raw score

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

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = 0.28804$.

Table 23. Trail making test: Part A

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	2	2	2	2	2	1	1	1	1	0	0	0	0	0	−1	−1	−1
3	4	4	4	4	3	3	3	3	3	2	2	2	2	1	1	1	1	1	0	0	0
4	5	5	5	5	4	4	4	4	4	3	3	3	3	2	2	2	2	2	1	1	1
5	6	6	6	6	5	5	5	5	5	4	4	4	4	3	3	3	3	3	2	2	2
6	7	7	7	7	6	6	6	6	6	5	5	5	5	4	4	4	4	4	3	3	3
7	8	8	8	8	7	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4
8	9	9	9	9	8	8	8	8	8	7	7	7	7	6	6	6	6	6	5	5	5
9	10	10	10	10	9	9	9	9	9	8	8	8	8	7	7	7	7	7	6	6	6
10	11	11	11	11	10	10	10	10	10	9	9	9	9	8	8	8	8	8	7	7	7
11	12	12	12	12	11	11	11	11	11	10	10	10	10	9	9	9	9	9	8	8	8
12	13	13	13	13	12	12	12	12	12	11	11	11	11	10	10	10	10	10	9	9	9
13	14	14	14	14	13	13	13	13	13	12	12	12	12	11	11	11	11	11	10	10	10
14	15	15	15	15	14	14	14	14	14	13	13	13	13	12	12	12	12	12	11	11	11
15	16	16	16	16	15	15	15	15	15	14	14	14	14	13	13	13	13	13	12	12	12
16	17	17	17	17	16	16	16	16	16	15	15	15	15	14	14	14	14	14	13	13	13
17	18	18	18	18	17	17	17	17	17	16	16	16	16	15	15	15	15	15	14	14	14
18	19	19	19	19	18	18	18	18	18	17	17	17	17	16	16	16	16	16	15	15	15

Notes: Education adjustment applying the following formula: $NSS_{AE} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = -0.21832$.

Symbol Digit Modalities Test

Our results confirm previous studies on the effect of demographic variables on raw scores and demonstrate that education- and age-corrected norms are needed (Gilmore et al., 1983a; 1983b; Richardson & Marottoli, 1996; Strauss et al., 2006). Age and education accounted significantly for the raw score variance of SDMT (see Table 2). Sex differences were not observed, indicating no need to control this demographic variable. This test is the one most affected by education in the series of tests presented in this paper. It is clear that education adjustments are needed for a correct analysis of scores. In fact, Table 25 shows a three-point adjustment (up or down) of NSS_A to $NSS_{A\&E}$. This kind of adjustment is specifically important in cases of education higher than 12 years or lower than 9 years.

It is extremely difficult to compare our results with the normative tables of the Spanish manual (Smith, 2002) due to evident methodological and demographic differences (e.g., the manual includes only two education groups [cut-off >12] and the age

Table 24. Trail making test: Part B

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	2	2	2	2	1	1	1	0	0	0	0	−1	−1	−1	−2	−2
3	5	4	4	4	4	3	3	3	3	2	2	2	1	1	1	1	0	0	0	−1	−1
4	6	5	5	5	5	4	4	4	4	3	3	3	2	2	2	2	1	1	1	0	0
5	7	6	6	6	6	5	5	5	5	4	4	4	3	3	3	3	2	2	2	1	1
6	8	7	7	7	7	6	6	6	6	5	5	5	4	4	4	4	3	3	3	2	2
7	9	8	8	8	8	7	7	7	7	6	6	6	5	5	5	5	4	4	4	3	3
8	10	9	9	9	9	8	8	8	8	7	7	7	6	6	6	6	5	5	5	4	4
9	11	10	10	10	10	9	9	9	9	8	8	8	7	7	7	7	6	6	6	5	5
10	12	11	11	11	11	10	10	10	10	9	9	9	8	8	8	8	7	7	7	6	6
11	13	12	12	12	12	11	11	11	11	10	10	10	9	9	9	9	8	8	8	7	7
12	14	13	13	13	13	12	12	12	12	11	11	11	10	10	10	10	9	9	9	8	8
13	15	14	14	14	14	13	13	13	13	12	12	12	11	11	11	11	10	10	10	9	9
14	16	15	15	15	15	14	14	14	14	13	13	13	12	12	12	12	11	11	11	10	10
15	17	16	16	16	16	15	15	15	15	14	14	14	13	13	13	13	12	12	12	11	11
16	18	17	17	17	17	16	16	16	16	15	15	15	14	14	14	14	13	13	13	12	12
17	19	18	18	18	18	17	17	17	17	16	16	16	15	15	15	15	14	14	14	13	13
18	20	19	19	19	19	18	18	18	18	17	17	17	16	16	16	16	15	15	15	14	14

Notes: Education adjustment applying the following formula: $NSS_{AE} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = -0.27320$.

Table 25. Symbol-digit modalities test total score

SSS_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	4	4	4	3	3	3	2	2	2	2	1	1	1	0	0	0	−1	−1
3	6	6	6	5	5	5	4	4	4	3	3	3	3	2	2	2	1	1	1	0	0
4	7	7	7	6	6	6	5	5	5	4	4	4	4	3	3	3	2	2	2	1	1
5	8	8	8	7	7	7	6	6	6	5	5	5	5	4	4	4	3	3	3	2	2
6	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	4	4	4	3	3
7	10	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6	5	5	5	4	4
8	11	11	11	10	10	10	9	9	9	8	8	8	8	7	7	7	6	6	6	5	5
9	12	12	12	11	11	11	10	10	10	9	9	9	9	8	8	8	7	7	7	6	6
10	13	13	13	12	12	12	11	11	11	10	10	10	10	9	9	9	8	8	8	7	7
11	14	14	14	13	13	13	12	12	12	11	11	11	11	10	10	10	9	9	9	8	8
12	15	15	15	14	14	14	13	13	13	12	12	12	12	11	11	11	10	10	10	9	9
13	16	16	16	15	15	15	14	14	14	13	13	13	13	12	12	12	11	11	11	10	10
14	17	17	17	16	16	16	15	15	15	14	14	14	14	13	13	13	12	12	12	11	11
15	18	18	18	17	17	17	16	16	16	15	15	15	15	14	14	14	13	13	13	12	12
16	19	19	19	18	18	18	17	17	17	16	16	16	16	15	15	15	14	14	14	13	13
17	20	20	20	19	19	19	18	18	18	17	17	17	17	16	16	16	15	15	15	14	14
18	21	21	21	20	20	20	19	19	19	18	18	18	18	17	17	17	16	16	16	15	15

Notes: Education adjustment applying the following formula: $NSS_{A\&E} = NSS_A - (\beta^*(Education_{(years)} - 12))$, where $\beta = 0.32136$.

groups stop at 65+ years). Due to the significant effect of education on raw score, this oversimplification for clinical purposes, especially in elderly subjects, appears inadequate.

Finally, it is worth commenting that in a community-based sample, SDMT was not significantly affected by age, education, and sex (Sheridan et al., 2006). It is probable that this was the result of a combination of influential age and education range restrictions and a low number of subjects.

Final Comments

One of the strengths of this normative sample is its inclusion of a wide range of educational levels (from illiterate to higher educated) and the provision of education-based adjustments. Tables with both age and education adjustments may be

particularly useful to reduce the risk of misdiagnosing cognitive impairment in elderly Spanish subjects. These kinds of adjustments should improve diagnostic accuracy of cognitive impairment because they can better predict the patient's decline from premorbid status and give information about their expected premorbid scores (Silverberg & Millis, 2009).

One of the advantages of the NEURONORMA norms is that they allow the valid comparison of a subject's performance across all normed tests. This is due to the NEURONORMA practice of simultaneously co-norming multiple tests. Separate NEURONORMA publications (this issue) report on other tests included in the project: Boston Naming Test (Kaplan, Goodglass, & Weintraub, 2001); Token Test (De Renzi & Faglioni, 1978); Selected test of the Visual Object and Space Perception Battery (Warrington & James, 1991); Judgment of Line Orientation (Benton, Hannay, & Varney, 1975, 1994); Rey–Osterrieth Complex Figure (Osterrieth, 1944; Rey, 1941); Free and Cued Selective Reminding Test (Buschke, 1973, 1984); Verbal Fluency (Ramier & Hécaen, 1970) including three semantic fluency tasks (animals, fruit and vegetables, and kitchen tools), three formal lexical tasks (words beginning with p, m, and r), and three excluded letter fluency task (excluded a, e, and s) (Crawford, Wright, & Bate, 1995); Stroop Color–Word Interference Test (Golden, 1978; Stroop, 1935); Tower of London Drexel University version (Culbertson & Zillmer, 2001). Recently, some authors have concluded that raw scores without sociodemographic corrections are more appropriate to determine patient's acquired brain dysfunction than demographic-adjusted scores (Silverberg & Millis, 2009).

The limitations of NEURONORMA norms have been previously discussed and are mainly related to the techniques of recruitment employed (*see* Peña-Casanova et al., 2009). It is, however, important to point out that the current norms derive from several local Spanish samples who may not reflect the full diversity of cultural experiences of Spanish-speaking people. The data of this study could be used to assess Spanish-speaking subjects from different countries, provided that the subject's age and education are taken into account (Ostrosky-Solís, Lozano, Ramirez, & Ardila, 2007; Ramirez, Ostrosky-Solís, Fernández, & Ardila, 2005). Consequently, the clinician must determine the degree of similarity between the individual subject tested and the demographic characteristics of the normative sample when deciding whether to use NEURONORMA norms for a given subject.

Despite its limitations, this study reflects the largest normative study to date for neuropsychological performance of older Spanish subjects co-normed attention/WM tests. As this tasks are frequently multifactorial and overlap with other neuropsychological domains (e.g., executive functions, memory, switching capacity, mental tracking), future studies should analyze correlations between present tests (e.g., SDMT and TMT, as in McCaffrey, Krahula, Heimberg, Keller, & Purcell, 1988) and with other tests (e.g., Tower of London, Stroop Test) included in the NEURONORMA Battery.

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Conflict of Interest

None declared.

Appendix

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