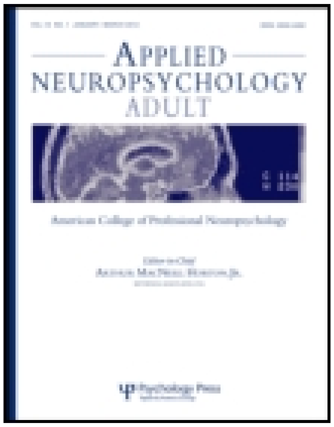

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Normatization of the Symbol Digit Modalities Test-Oral Version in a Latin American Country

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The aim of this study was to standardize the Symbol Digit Modalities Test (SDMT)-Oral version in a healthy population living in Argentina and to analyze the influence that age, gender, and education have on the SDMT. Secondarily, it is intended to analyze the performance of patients with multiple sclerosis (MS) on this test. Two hundred ninety-seven healthy participants were evaluated; they had an average age of 39.28 years and 13.87 years of schooling; 77.8% were women. The sample was segmented according to age in three groups: younger than 35 years old, 36 to 50 years old, and 51 to 70 years old. The sample was also segmented according to years of schooling in three groups: 11 years or less, 12 to 16 years, and more than 16 years. All participants were evaluated with the oral version of the SDMT. A clinical sample of 111 patients with MS was also assessed. The mean on the SDMT for the total sample was 51.34 ($SD = 12.76$). The differences were significant between all groups, $p < .05$, according to age. The participants with a higher level of education performed better than did those with moderate education and those with less schooling, $p < .05$. There was a significant difference between patients with MS and healthy controls, $p < .01$. The SDMT is influenced by age as well as by schooling, although not by gender. The norms displayed here will be useful to accurately evaluate the yield of the patients in the neuropsychological clinic when comparing them with their group of reference. It was also demonstrated that the SDMT can discriminate between patients with MS and healthy people.

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Key words: *age, education, neuropsychological assessment, normative data, Symbol Digit Modalities Test*

BACKGROUND

"Attention" refers to different capacities or processes related to how the organism becomes receptive to stimuli and how it may begin processing incoming or attended-to excitation, internally or externally (Lezak, Howieson, & Loring, 2004). Processing speed is one of the most basic capacities underlying neurocognitive test performance (Noh et al., 2010), and it typically has been defined as the time needed to carry out a cognitive task or the amount of work done in a certain period of time (DeLuca, Chelune, Tulsky, Lengenfelder, & Chiaravalloti, 2004).

The Symbol Digit Modalities Test (SDMT) is one of the most widespread attention and visual tracking tools. In this study, the patients are shown an array of symbols and matching numbers. Then, the patient must write down the corresponding number of the symbol as rapidly as possible. It is a simple and easily administered test. The written version was originally published in 1973 and was revised in 1982 by A. Smith as a screening tool for cerebral dysfunction in children and adults (Spreen, Sherman, & Strauss, 2006). In Wechsler's Intelligence Scale, the task was reversed and the examinee must write the symbols rather than the numbers (Wechsler, 1955). There is also an oral version, in which the numbers are said aloud. This version is widely used in the assessment of patients with brain impairment and upper-limb motor difficulties, such as patients with stroke (Koh et al., 2011), traumatic brain injury (Felmingham, Baguley, & Green, 2004), and multiple sclerosis (MS). In fact, the test is part of two other neuropsychological tests— the Brief Repeatable Battery of Neuropsychological Tests in MS (BRBN-MS; Rao & The Cognitive Function Study Group of the National Multiple Sclerosis Society, 1990) and the Minimal Assessment of Cognitive Function in MS (Benedict et al., 2002). It has proven to be reliable and appropriate for this clinical population (Benedict et al., 2008; Drake et al., 2010) and is strongly associated with measurement tools of brain images by magnetic resonance imaging (Parmenter, Weinstock-Guttman, Garg, Munschauer, & Benedict, 2007; Sepulcre et al., 2006; Strober et al., 2009). In addition, there are numerous alternative forms suitable to conduct periodic reevaluations (Benedict et al., 2012).

In neuropsychological clinical practice, to classify performance on a specific test of a patient with cerebral damage as normal or pathological, it is necessary to count on reliable normative data. In addition, normative studies should take into account several variables that may affect test performance. The normative data published several years ago (e.g., those of Smith, 1982) are obsolete for the current population because of the influence of the so-called Flynn effect (Dickinson & Hiscock, 2011), which describes a systematic increase in the test scores from one generation to the next. Additionally, it is not adequate to use population-based normative data from other countries because cultural variables influence test performance (Ardila, 2005). For example, the concept of speed differs between cultures and determines different attitudes toward time-dependent tasks (Agranovich, Panter, Puente, & Touradji, 2011).

Finally, it is widely recognized that the level of education influences many neuropsychological tests and thus must be taken into account when interpreting the yield of a patient (Rosselli & Ardila, 2003; Yassuda et al., 2009), especially in tests involving two cognitive abilities: those of controlled processes and conceptualization (Le Carret et al., 2003). The negative impact of low education in neuropsychological performance may be even stronger than that of depression (Avila et al., 2009). A low level of education implies not only that the person did not acquire specific abilities or cultural knowledge or receive appropriate cognitive stimulation, but also that, being part of an underprivileged social class, the person is immersed in a culturally poor environment, deprived of an adequate diet and cognitive or motor stimulation since an early age. All these socioeconomic factors affect brain development and functional brain organization (Noble, McCandliss, & Farah, 2007).

Many authors highlight the effect that age has on neuropsychological performance (Cullum, Thompson, & Heaton, 1989; Lam et al., 2013; McAvinue et al., 2012; Salthouse, 2004). However, the effect is not always the same during a person's lifespan (Weintraub et al., 2013). When an attention test like the SDMT is implemented in people younger than 50 years old, age does not affect performance (Sheridan et al., 2006; Tamayo et al., 2012). But when it is implemented in people older than 60 years old, test performance declines (Hickman, Howieson, Dame, Sexton, & Kaye, 2000), mainly due to brain aging (Lezak et al., 2004, pp. 295–301).

The effects of gender on neuropsychological performance are modest compared with those of age and education ("Assessment: Neuropsychological Testing of Adults," 1996). It has been recognized that men and women perform differently in arithmetic, visuospatial, and verbal aptitudes (Lezak et al., 2004; Saykin et al., 1995). Conversely, in psychomotor speed and attention tasks, the effect of gender is more controversial (Lezak et al., 2004). For these reasons, gender, age, and the level of education should be considered when developing normative data.

Normative data published by the original author of the SDMT (Smith, 1982) took into account age and schooling. However, the oral version was implemented after the written version, and the implemented sample was not chosen appropriately (Spreen et al., 2006). In a revision, Sheridan et al. (2006) listed 13 normative studies based on nonclinical populations, 5 of which used the oral version. In addition, the authors reported norms of the written and oral versions for the American population considering the variables of age, gender, level of education, and socioeconomic status, although they did not find that these variables had any influence (Sheridan et al., 2006). Nocentini, Giordano, Di Vincenzo, Panella, and Pasqualetti (2006) published normative data for the Italian population considering gender, age, and education. The authors observed a decrement in the SDMT score regarding age and an increase regarding education, but they did not find differences between men and women.

Argentina has its own cultural characteristics, and regarding education particularly, even though it shows high levels of education according to the information provided by national and international organizations (UN Development Program, n.d.), there is still a percentage of the population with a low education rate, many of whom have not completed primary and/or secondary school, especially among the lower-income groups (Cimientos. Fundación para la Igualdad de Oportunidades Educativas, n.d.; UNICEF, n.d.). However, in Argentina, there is a lack of updated normative data for the SDMT. The aim of the present study was to standardize the SDMT-Oral version in a healthy population with residence in Argentina and to analyze the influence of age, gender, and especially the heterogeneous educational levels in this test performance. A secondary aim was to compare SDMT performance of healthy controls with that of a clinical population of patients with MS.

A significant difference in favor of the healthy sample was expected to be found, demonstrating the sensibility of the test.

METHOD

Participants

From a total of 300 healthy participants, 3 were excluded for scoring more than 9 points in the Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996). The data of 297 participants were analyzed; 77.8% were women ($N = 231$) with an age range of 19 to 70 years old and with 3 to 21 years of schooling. The sample was selected among institutions (Neuroscience Institute of Buenos Aires–INEBA and Hospital J. M. Ramos Mejia) from Buenos Aires City and its suburbs via word of mouth, advertisements, and fliers distributed through community agencies. Interviews were taken with the people who volunteered, and after that, they were selected to match in age, gender, and level of education with an MS sample that took part in research conducted in the aforementioned institutions. Data were collected during an investigation of cognitive impairment in patients with MS (Cáceres, Vanotti, Rao, & the RECONEM [Cognitive Impairment Survey in Multiple Sclerosis Patients] Workgroup, 2011), in which the present sample was the healthy control group. Due to the high prevalence of this disease in women, this sample has a high frequency of women.

Inclusion criteria for the healthy control group was: aged 18 to 70 years old, a BDI score less than 9 points, a Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) score greater than 26 points, and 3 or more years of schooling. Exclusion criteria included antecedents of neuropsychiatric disease, traumatic brain injury, drugs or alcohol abuse, subjective complaint of loss of memory, or other systemic diseases that can affect the cognitive yield. All participants signed an informed consent approved by the board of ethics of the institution.

The sample was segmented by age in three groups: younger than 35 years old, 36 to 50 years old, and 51 to 70 years old. The sample was also segmented by schooling in three groups: less than 12 years, 12 to 16 years, and more than 16 years.

The clinical sample consisted of 111 patients with MS with a mean age of 40.8 years old ($SD = 11.3$ years) and a mean education of 13.6 years of schooling ($SD = 3.1$ years). The Expanded Disability Status Scale (EDSS) mean was 3.1 ($SD = 1.8$), and the average disease duration was 7.4 years ($SD = 6.8$). The most common clinical presentation among participants was relapsing–remitting ($n = 93$, 83.8%), followed by secondary progressive ($n = 10$, 9.0%), primary progressive ($n = 4$, 3.6%), and relapsing progressive ($n = 4$, 3.6%). Inclusion criteria were age 18 years or older and all clinical forms of MS according to Poser et al. (1983) and McDonald's criteria (McDonald et al., 2001). Exclusion criteria included psychiatric syndromes, visual and hearing deficits, history of alcohol or drug abuse and dependence, depression (as measured by BDI scores > 10), physical disability that could impair appropriate performance of the tests, uncontrolled systemic disease, and the presence of any disease that could cause cognitive impairment (e.g., endocrinological, toxic, genetic–degenerative, metabolic, infectious diseases). More information on selection of the MS sample can be found in Cáceres et al. (2011).

Materials and Procedure

The SDMT was administered as part of an evaluation of the BRBN-MS (Rao & The Cognitive Function Study Group of the National Multiple Sclerosis Society, 1990). During the test, each participant was required to substitute a number (1–9) orally with up to 120 geometric figures randomly displayed on the sheet. Each number corresponded with a particular geometric symbol given at the top of the assessment sheet. Testing time was limited to 90 s, and correct verbal responses were recorded. A larger number of correct answers given within the time limit represented better switching attention and information-processing speeds in an individual.

Trained neuropsychologists were in charge of the evaluation and had read the manual and practiced implementing the study previously with supervision.

Statistical Analysis

Analysis of variance was performed on two factors (age and level of education) to determine the influence that these variables had on performance in the healthy sample. A student's t test was implemented to analyze the difference between both samples.

RESULTS

Demographic Data

The sample group had an average age of 39.28 years ($SD = 11.69$ years), with a range of 19 to 70 years, and a mean education of 13.67 years ($SD = 3.51$ years), with a range of 3 to 21 years. The mean SDMT score for the total sample was 51.34 ($SD = 12.76$), with a range of 15 to 98. The mean BDI score was 4.58 ($SD = 3.67$). The distribution of the SDMT variable shows a normal curve, KS = 1.16, $p = .136$.

There were no significant differences between women and men on the SDMT, $t(295) = -0.913$, $p = .362$, $d = 0.1$, and no significant differences in years of schooling, $t(295) = -0.375$, $p = .708$, $d = 0.0$. However, women were older than men, $t(295) = -2.27$, $p = .023$, $d = 0.3$. Table 1 shows demographic data and performance on the SDMT according to gender. When a group of 66 women from the sample was selected to match the 66 men in age (±2 years) and years of schooling (±2 years), there was no significant difference on the SDMT, $t(130) = -0.591$, $p = .556$, $d = 0.1$.

TABLE 1
Demographic Data and Performance on the SDMT According to Gender

	Men N = 66			*Women N = 231*		
	Mean	*SD*	*Range*	*Mean*	*SD*	*Range*
Age	36.41	11.927	19–60	40.1	11.528	20–70
Education	13.53	3.747	5–21	13.71	3.451	3–20
SDMT	52.61	13.244	21–95	50.98	12.629	15–98

SDMT = Symbol Digit Modalities Test.

Performance on the SDMT According to Age and Education

Table 2 shows the yield on the SDMT of the total sample according to age and education. The univariate analysis considering the SDMT as the dependent variable and age and education as grouping variables showed that both age, $F(2, 288) = 10.9$, $MSE = 1{,}472.32$, $p < .001$, and education, $F(2, 288) = 12.89$, $MSE = 1{,}741.62$, $p < .001$, have an influence but that there is no significant interaction between these variables, $F(4, 288) = 0.89$, $MSE = 121.45$, $p = .465$. The same results were found when the model was controlled for gender (data not shown).

As shown in Figure 1, SDMT performance declined as age increased. Tukey's post-hoc analyses showed that participants aged 35 years old or younger had higher performance than those aged 36 to 50 years old ($p = .007$) and than aged 51 to 70 years old ($p < .001$). The group aged 36 to 50 years old showed higher scores than those of participants aged 51 to 70 years old ($p = .002$). These data are shown in Table 3.

As shown in Figure 2, SDMT performance increased with more years of schooling. With respect to education, Tukey's post-hoc analyses showed that the participants with the upper level of education performed better than those with the moderate level of education ($p < .001$)

TABLE 2
Yield on the SDMT According to Age and Education

			SDMT	
Age	*Education*	*N*	*Mean*	*SD*
19–35 years old	3–11 years	13	45.31	11.49
	12–16 years	63	56.43	11.5
	More than 16 years	55	56.29	12.06
36–50 years old	3–11 years	23	44.22	9.64
	12–16 years	48	49.92	12.51
	More than 16 years	40	54.88	12.62
51– 70 years old	3–11 years	20	39.1	10.13
	12–16 years	27	44.93	10.83
	More than 16 years	8	50.63	9.47
	Total	297	51.34	12.76

SDMT = Symbol Digit Modalities Test.

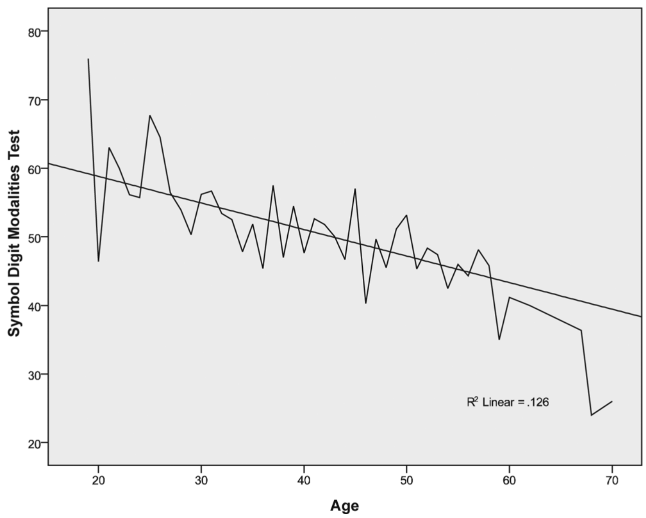

FIGURE 1 SDMT score according to age. SDMT scores declined with age.

TABLE 3
Performance on the SDMT According to Age

		SDMT Score		
Age	*N*	*Mean*	*SD*	*Range*
19–35 years old	131	55.27	12.11	16–95
36–50 years old	111	50.52	12.54	15–98
51–70 years old	55	43.64	10.95	20–71

SDMT = Symbol Digit Modalities Test.

and those with less schooling ($p < .001$). The group with moderate education performed better than did those with less education, although this difference did not reach statistical significance ($p = .078$). Data are presented in Table 4.

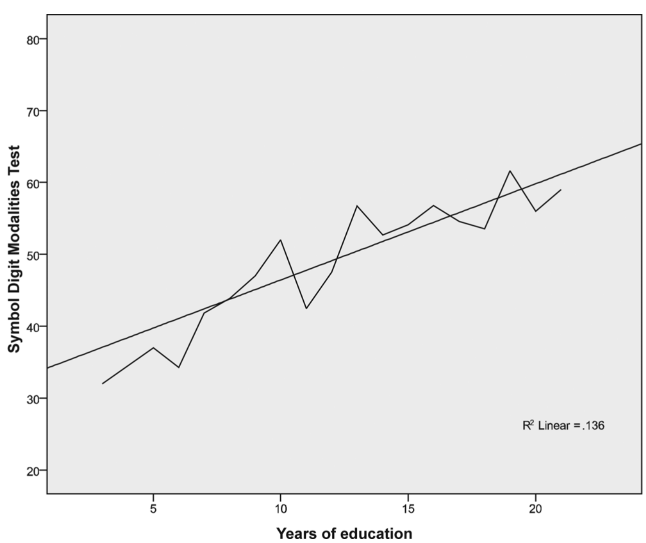

FIGURE 2 SDMT score according to education. SDMT increased proportionally to education.

TABLE 4
Performance on the SDMT According to Years of Education

		SDMT		
Education	*N*	*Mean*	*SD*	*Range*
3–11 years	56	42.64	10.43	16–65
12–16 years	138	51.91	12.49	15–91
More than 16 years	103	55.30	12.1	30–98

SDMT = Symbol Digit Modalities Test.

A linear regression analysis of the SDMT scores (dependent variable) was performed considering age and years of schooling. These predictors explained less than half of the percent of the variance in SDMT ($R^2 = .205$), significantly, $F(2, 293) = 37.8$, $p < .01$. Both age ($\beta = -.27$, $p < .01$) and years of schooling ($\beta = .29$, $p < .01$) had significant effects on SDMT.

Comparison With Patients With Multiple Sclerosis

There were no significant differences between the healthy group and patients with MS in age, $t(405) = -1.136$, $p = .257$, $d = 0.1$, education, $t(405) = 0.006$, $p = .995$, $d = 0.0$, or gender distribution. SDMT performance was significantly different, $t(405) = 8.777$, $p < .01$, $d = 0.9$, in favor of the healthy control group ($M = 51.34$, $SD = 12.78$; $M = 38.5$, $SD = 14.08$).

DISCUSSION

The use of appropriate and specific neuropsychological tests and their quick and easy implementation are necessary to assess cognitive dysfunction caused by cerebral damage. The SDMT is a useful test for the evaluation of cognitive deterioration, especially for alterations in attention and slow processing speed. The oral version can be implemented in different clinical populations, including patients who present mobility impairment in their upper limbs.

Normative data based on different countries' populations, like the United States (Sheridan et al., 2006; Smith, 1982) and Italy (Nocentini et al., 2006), are available and help interpret performance on the SDMT-Oral version. The primary aim of this investigation was to collect updated normative data on the SDMT in a sample of demographically representative participants of the Argentinian population, taking into account the variables of age and schooling rate. The displayed data show that the SDMT is influenced by age and by schooling rate, although not by gender. These results are in agreement with those of Nocentini et al. (2006) and

Boringa et al. (2001) but are in disagreement with those of Sheridan et al. (2006), who did not find that the mentioned variables influenced test results in any way. Nevertheless, it is necessary to highlight that Sheridan et al. administered the oral version after the written version of the test, which can affect the performance of the samples.

Neither Nocentini et al. (2006) nor Sheridan et al. (2006) found that gender had any effect. In addition, our sample was composed of 77.8% of women; therefore, men might not be adequately represented, thus covering the effect that gender might have on SDMT performance. Nevertheless, when a subgroup of women was matched to one of men, results remained the same. Therefore, it can be argued that this variable does not influence SDMT performance, as was proven in the written version of the SDMT and other tests of attention in a Spanish population (Tamayo et al., 2012). However, other researchers have found that women outperformed men in the oral version of the SDMT (Boringa et al, 2001).

With respect to age, it was found that SDMT performance decreases as age increases. One of the reasons for this is that brain aging negatively affects attention tests that have to do with selective attention, processing speed, and executive control (Borghesani et al., 2013; Kerchner et al., 2012; Müller-Oehring, Schulte, Rohlfing, Pfefferbaum, & Sullivan, 2013). There are other factors that may influence the relationship between age and cognition: age-related changes in personality, such as anxiety and apathy (Beaudreau & O'Hara, 2009; Brodaty, Altendorf, Withall, & Sachdev, 2010), and presence of morbidity associated with cognitive deterioration, such as hypertension (Scuteri et al., 2011). On the other hand, the cognitive reserve (high education and participation in intellectual activities) acts as a protector against deterioration (Schumacher & Martin, 2009). However, with respect to the last hypothesis, it must be mentioned that in this case, level of education did not interact with the effect of age.

Independent of age, the level of education has an important positive effect on the SDMT. Higher-educated people have different brain function. In addition, a high education is generally associated with a rich environment and participation in intellectual activities, all of which represent a general high cognitive reserve (Stern, 2012).

In the Italian sample, Nocentini et al. (2006) obtained a mean of 50.7 ($SD = 14.1$) when applying the SDMT. In the American sample, Sheridan et al. (2006) found a mean of 54.9 ($SD = 1.1$) in participants aged 20 to 29 years old and a mean of 52.1 ($SD = 1.5$) among those aged 30 to 39 years old. A recent BRBN-MS normatization conducted within a Spanish population (Duque et al., 2012) showed a mean of 49.1 ($SD = 13$). These results are relatively similar to those reported here, which is something that could indicate that culture may not have a significant impact on SDMT performance. In the Netherlands, however, Boringa et al. (2001) found a mean of 56.1 ($SD = 12.4$)—a higher figure than the 51.34 ($SD = 12.76$) reported here. It has been suggested that differences in cognitive performance in a processing-speed test, such as the SDMT, between people from diverse cultures can be regarded as differences in the level of education (Harris, Wagner, & Cullum, 2007). Nevertheless, there is no evidence to suggest that the educational level of Boringa et al.'s sample differs from the one studied here. At this point, it should be mentioned that other researches demonstrated that cultural background affects the SDMT (Agranovich et al., 2011); therefore, further research is needed to elucidate this issue.

With respect to the secondary aim of the present research, it can be concluded that the SDMT is a suitable test to discriminate between patients with MS and healthy people from Argentina. This was demonstrated previously in a wide range of research (Benedict et al., 2006; Deloire et al., 2006; Parmenter et al., 2007; Sepulcre et al., 2006).

One of the strengths of the normative sample used here is that it represents appropriately each educational level and age group. Thereby, it allows clinicians to use an appropriate neuropsychological tool when considering the demographic characteristics of their patients. That represents important opportunities for countries where people have different educational levels. Individuals with low levels of education were represented in the sample adequately.

One thing that can be regarded as a weakness in this study was that the present normative data were obtained from a sample selected in previous research that had a high prevalence of women. Nevertheless, those data were very useful in neuropsychological practice, and we hope this will expand the number of clinical tools available for detecting cognitive impairment. Future investigations could consider the different socioeconomic levels and cultural diversities that exist in Argentina.

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REFERENCES

Agranovich, A. V., Panter, A. T., Puente, A. E., & Touradji, P. (2011). The culture of time in neuropsychological assessment: Exploring the effects of culture-specific time attitudes on timed test performance in Russian and American samples. *Journal of the International Neuropsychological Society*, *17*, 692–701. doi:10.1017/S1355617711000592

Ardila, A. (2005). Cultural values underlying psychometric cognitive testing. *Neuropsychology Review*, *15*, 185–195. doi:10.1007/s11065–005-9180-y

Assessment: Neuropsychological testing of adults. Considerations for neurologists. Report of the Therapeutics, & Technology Assessment Subcommittee of the American Academy of Neurology. (1996). *Neurology*, *47*, 592–599.

Avila, R., Moscoso, M. A. A., Ribeiz, S., Arrais, J., Jaluul, O., & Bottino, C. M. C. (2009). Influence of education and depressive symptoms on cognitive function in the elderly. *International Psychogeriatrics*, *21*, 560–567. doi:10.1017/S1041610209008928

Beaudreau, S. A., & O'Hara, R. (2009). The association of anxiety and depressive symptoms with cognitive performance in community-dwelling older adults. *Psychology & Aging*, *24*, 507–512. doi:10.1037/a0016035.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the beck depression inventory-II*. San Antonio, TX: Psychological Corporation.

Benedict, R. H. B., Cookfair, D., Gavett, R., Gunther, M., Munschauer, F., Garg, N., & Weinstock-Guttman, B. (2006). Validity of the Minimal Assessment of Cognitive Function in Multiple Sclerosis (MACFIMS). *Journal of the International Neuropsychological Society*, *12*, 549–558. doi:10.10170S1355617706060723

Benedict, R. H. B., Duquin, J. A., Jurgensen, S., Rudick, R. A., Feitcher, J., Munschauer, F. E., … Weinstock-Guttman, B. (2008). Repeated assessment of neuropsychological deficits in multiple sclerosis using the Symbol Digit Modalities Test and the MS neuropsychological screening questionnaire. *Multiple Sclerosis*, *14*, 940–946. doi:10.1177/1352458508090923

Benedict, R. H. B., Fischer, J. S., Archibald, C. J., Arnett, P. A., Beatty, W. W., Bobholz, J., … Munschauer, F. (2002). Minimal neuropsychological assessment of MS patients: A consensus approach. *Clinical Neuropsychologist*, *16*, 381–397. doi:10.1076/clin.16.3.381.13859

Benedict, R. H. B., Smerbeck, A., Parikh, R., Rodgers, J., Cadavid, D., & Erlanger, D. (2012). Reliability and equivalence of alternate forms for the Symbol Digit Modalities Test: Implications for multiple sclerosis clinical trials. *Multiple Sclerosis*, *18*, 1320–1325. doi:10.1177/1352458511435717

Borghesani, P. R., Madhyastha, T. M., Aylward, E. H., Reiter, M. A., Swarny, B. R., … Willis, S. L. (2013). The association between higher order abilities, processing speed, and age are variably mediated by white matter integrity during typical aging. *Neuropsychologia*, *51*, 1435–1444. doi:10.1016/j.neuropsychologia.2013.03.005

Boringa, J. B., Lazeron, R. H., Reuling, I. E., Adèr, H. J., Pfennings, L., Lindeboom, J., … Polman, C. H. (2001). The brief repeatable battery of neuropsychological tests: Normative values allow application in multiple sclerosis clinical practice. *Multiple Sclerosis*, *7*, 263–267.

Brodaty, H., Altendorf, A., Withall, A., & Sachdev, P. (2010). Do people become more apathetic as they grow older? A longitudinal study in healthy individuals. *International Psychogeriatrics*, *22*, 426–436. doi:10.1017/S1041610209991335

Cáceres, F., Vanotti, S., Rao, S., & The RECONEM [Cognitive Impairment Survey in Multiple Sclerosis Patients] Workgroup. (2011). Epidemiological characteristics of cognitive impairment of multiple sclerosis patients in a Latin American country. *Journal of Clinical and Experimental Neuropsychology*, *33*, 1094–1098. doi:10.1080/13803395.2011.603690

Cimientos. Fundación para la Igualdad de Oportunidades Educativas. (n.d.). *La educación argentina en números* [*Argentine education in numbers*]. Retrieved from http://www.cimientos.org/archivos/La_educacion_argentina_en_numeros_N_1.pdf

Cullum, C. M., Thompson, L. L., & Heaton, R. K. (1989). The use of the Halstead-Reitan test battery with older adults. *Clinics in Geriatric Medicine 5*, 595–610.

Deloire, M. S. A., Bonnet, M. C., Salort, E., Arimone, Y., Boudineau, M., Petry, K. G., & Brochet, B. (2006). How to detect cognitive dysfunction at early stages of multiple sclerosis? *Multiple Sclerosis*, *12*, 445–452. doi:10.1191/1352458506ms1289oa

DeLuca, J., Chelune, G. J., Tulsky, D. S., Lengenfelder, J., & Chiaravalloti, N. D. (2004). Is speed of processing or working memory the primary information processing deficit in multiple sclerosis? *Journal of Clinical and Experimental Neuropsychology*, *26*, 550–562. doi:10.1080/13803390490496641

Dickinson, M. D., & Hiscock, M. (2011). The flynn effect in neuropsychological assessment. *Applied Neuropsychology*, *18*, 136–142. doi:10.1080/09084282.2010.547785

Drake, A. S., Weinstock-Guttman, B., Morrow, S. A., Hojnacki, D., Munschauer, F. E., & Benedict, R. H. B. (2010). Psychometrics and normative data for the multiple sclerosis functional composite: Replacing the PASAT with the symbol digit modalities test. *Multiple Sclerosis*, *16*, 228–237. doi:10.1177/1352458509354552

Duque, P., Ibáñez, J., Del Barco, A., Sepulcre, J., De Ramón, E., & Fernández-Fernández, O., (2012). Normalización y validación de la batería neuropsicológica breve como test neuropsicológico de referencia en la esclerosis múltiple [Normalization and validation of the Brief Neuropsychological Battery as the reference neuropsychological test in multiple sclerosis]. *Revista de Neurología*, *54*, 263–270.

Felmingham, K. L., Baguley, I. J., & Green, A. M. (2004). Effects of diffuse axonal injury on speed of information processing following severe traumatic brain injury. *Neuropsychology*, *18*, 564–571. doi:10.1037/0894-4105.18.3.564

Folstein, M. F., Folstein, S., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*, 189–198.

Harris, J. G., Wagner, B., & Cullum, C. M. (2007). Symbol vs. digit substitution task performance in diverse cultural and linguistic group. *The Clinical Neuropsychologist*, *21*, 800–810. doi:10.1080/13854040600801019

Hickman, S. E., Howieson, D. B., Dame, A., Sexton, G., & Kaye, J. (2000). Longitudinal analysis of the effects of the aging process on neuropsychological test performance in the healthy young-old and oldest-old. *Developmental Neuropsychology*, *17*, 323–337.

Kerchner, G. A., Racine, C. A., Hale, S., Wilheim, R., Laluz, V., Miller, B. L., & Kramer, J. H. (2012). Cognitive processing speed in older adults: Relationship with white matter integrity. *PLoS One*, *7*, e50425. doi:10.1371/journal.pone.0050425

Koh, C. L., Lu, W. S., Chen, H. C., Hsueh, I. P., Hsieh, J. J., & Hsieh, C. L. (2011). Test–retest reliability and practice effect of the oral-format Symbol Digit Modalities Test in patients with stroke. *Archives of Clinical Neuropsychology*, *26*, 356–363. doi:10.1093/arclin/acr029

Lam, M., Eng, G. K., Rapisarda, A., Subramaniam, M., Kraus, M., Keefe, R. S. E., & Collinson, S. L. (2013). Formulation of the age–education index: Measuring age and education effects in neuropsychological performance. *Psychological Assessment*, *25*, 61–70. doi:10.1037/a0030548

Le Carret, N., Lafont, S., Letenneur, L., Dartigues, J., Mayo, W., & Fabrigoule, C. (2003). The effect of education on cognitive performances and its implication for the constitution of the cognitive reserve. *Developmental Neuropsychology*, *23*, 317–337. doi:10.1207/S15326942DN2303_1

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment* (4th ed.). New York, NY: Oxford.

McAvinue, L. P., Habekost, T., Johnson, K. A., Kyllingsbæk, S., Vangkilde, S., Bundesen, C., & Robertson, I. H. (2012). Sustained attention, attentional selectivity, and attentional capacity across the lifespan. *Attention, Perception & Psychophysiology*, *7*, 1570–1582. doi:10.3758/ s13414-012-0352-6.

McDonald, W. I., Compston, A., Edan, G., Goodkin, D., Hartung, H. P., Reingold, S. C., … Wolinsky, J. S. (2001). Recommended diagnostic criteria for multiple sclerosis: Guidelines from the international panel on the diagnosis of multiple sclerosis. *Annals of Neurology*, *50*, 121–127.

Müller-Oehring, E. M., Schulte, T., Rohlfing, T., Pfefferbaum, A., & Sullivan, E. V. (2013). Visual search and the aging brain: Discerning the effects of age-related brain volume shrinkage on alertness, feature binding, and attentional control. *Neuropsychology*, *27*, 48–59. doi:10.1037/a0030921.

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science*, *10*, 464–480. doi:10.1111/j.1467-7687.2007.00600.x

Nocentini, U., Giordano, A., Di Vincenzo, S., Panella, M., & Pasqualetti, P. (2006). The Symbol Digit Modalities Test-Oral version: Italian normative data. *Functional Neurology*, *21*, 93–96.

Noh, J., Kim, J. H., Hong, K. S., Kim, N., Nam, H. J., Lee, D., & Yoon, S. C. (2010). Factor structure of the neurocognitive tests: An application of the confirmative factor analysis in stabilized schizophrenia patients. *Journal of Korean Medical Science*, *25*, 276–282. doi:10.3346/jkms.2010.25.2.276

Parmenter, B. A., Weinstock-Guttman, B., Garg, N., Munschauer, F., & Benedict, R. H. B. (2007). Screening for cognitive impairment in multiple sclerosis using the Symbol Digit Modalities Test. *Multiple Sclerosis*, *13*, 52–57. doi:10.1177/1352458506070750

Poser, C. M., Paty, D., Scheimberg, L., McDonald, W. I., Davis, F. A., Ebers, G. C., … Tourtellotte, W. W. (1983). New diagnostic criteria for multiple sclerosis: Guidelines for research protocols. *Annals of Neurology*, *13*, 227–231.

Rao, S. M., & The Cognitive Function Study Group of the National Multiple Sclerosis Society. (1990). *A manual for the brief repeatable battery of neuropsychological tests in multiple sclerosis*. New York, NY: National Multiple Sclerosis Society.

Rosselli, M., & Ardila, A. (2003). The impact of culture and education on non-verbal neuropsychological measurements: A critical review. *Brain and Cognition*, *52*, 326–333. doi:10.1016/S0278-2626(03) 00170–2

Salthouse, T. A. (2004). What and when of cognitive aging. *Current Directions in Psychological Science*, *13*, 140–144. doi:10.1111/ j.0963-7214.2004.00293.x

Saykin, A. J., Gur, R. C., Gur, R. E., Shtasel, D. L., Flannery, K. A., Mozley, L. H., … Mozley, P. D. (1995). Normative neuropsychological test performance: Effects of age, education, gender and ethnicity. *Applied Neuropsychology*, *2*, 79–88. doi:10.1207/ s15324826an0202_5

Schumacher, V., & Martin, M. (2009). Comparing age effects in normally and extremely highly educated and intellectually engaged 65–80 year-olds: Potential protection from deficit through educational and intellectual activities across the lifespan. *Current Aging Science*, *2*, 200–204. doi:10.2174/1874609810902030200

Scuteri, A., Spazzafumo, L., Cipriani, L., Gianni, W., Corsonello, A., Cravello, L., … Sebastiani, M. (2011). Depression, hypertension, and comorbidity: Disentangling their specific effect on disability and cognitive impairment in older subjects. *Archives of Gerontology and Geriatrics*, *52*, 253–257. doi:10.1016/j.archger.2010.04.002

Sepulcre, J., Vanotti, S., Hernández, R., Sandoval, G., Cáceres, F., Garcea, O., & Villoslada, P. (2006). Cognitive impairment in patients with multiple sclerosis using the brief repeatable battery-neuropsychology test. *Multiple Sclerosis*, *12*, 187–195. doi:10.1191/1352458506ms1258oa

Sheridan, L. K., Fitzgerald, H. E., Adams, K. M., Nigg, J. T., Martel, M. M., Puttler, L. I., … Zucker, R. A. (2006). Normative symbol digit modalities test performance in a community-based sample. *Archives of Clinical Neuropsychology*, *21*, 23–28. doi:10.1016/ j.acn.2005.07.003

Smith, A. (1982). *Symbol Digit Modalities Test: Manual*. Los Angeles, CA: Western Psychological Services.

Spreen, O., Sherman, E. S., & Strauss, E. (2006). *A compendium of neuropsychological tests: Administration, norms and commentary* (3rd ed.). New York, NY: Oxford University Press.

Stern, Y. (2012). Cognitive reserve in ageing and Alzheimer's disease. *Lancet Neurology*, *11*, 1006–1012. doi:10.1016/S1474-4422(12)70191–6.

Strober, L., Englert, J., Munschauer, F., Weinstock-Guttman, B., Rao, S., & Benedict, R. H. B. (2009). Sensitivity of conventional memory tests in multiple sclerosis: Comparing the Rao Brief Repeatable Neuropsychological Battery and the Minimal Assessment of Cognitive Function in MS. *Multiple Sclerosis*, *15*, 1077–1084. doi:10.1177/1352458509106615

Tamayo, F., Casals-Coll, M., Sánchez-Benavides, G., Quintana, M., Manero, R. M., Rognoni, T., … Peña-Casanova, J. (2012). Estudios normativos españoles en población adulta joven (Proyecto NEURONORMA jóvenes): Normas para las pruebas span verbal, span visuoespacial, letter-number sequencing, trail making test y symbol digit modalities test [Spanish normative studies in a young adult population (NEURONORMA young adults Project): Norms for the verbal span, visuospatial span, Letter-Number Sequencing, Trail Making Test and Symbol Digit Modalities Test]. *Neurologia*, *27*, 319–329. doi:10.1016/j.nrl.2011.12.020

UNICEF. (n.d.). *La educación en cifras* [Education in numbers]. Retrieved from http://www.unicef.org/argentina/spanish/ estadisticas_educacion_Argentina_2011.pdf

UN Development Program. (n. d.). *Indicadores internacionales sobre desarrollo humano* [International indicators about human development]. Retrieved on from http://hdrstats.undp.org/es/paises/ perfiles/ARG.html

Wechsler, D. (1955). *Manual for the wechsler adult intelligence scale*. New York, NY: The Psychological Corporation.

Weintraub, S., Dikmen, S. S., Heaton, R. K., Tulsky, D. S., Zelazo, P. D., Bauer, P. J., … Gershon, R. C. (2013). Cognition assessment using the NIH Toolbox. *Neurology*, *80*(Suppl. 3), S54–S64. doi:10.1212/WNL.0b013e3182872ded

Yassuda, M., Diniz, B., Flaks, M., Viola, L., Pereira, F., Nunes, P., & Forlenza, O. V. (2009). Neuropsychological profile of Brazilian older adults with heterogeneous educational backgrounds. *Archives of Clinical Neuropsychology*, *24*, 71–79. doi:10.1093/arclin/acp009