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Multivariate Base Rates of Low Scores on Tests of Learning and Memory Among Latino Adult Populations

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Abstract

Objective: To determine the prevalence of low scores for two neuropsychological tests with five total scores that evaluate learning and memory functions. **Method:** $N = 5402$ healthy adults from 11 countries in Latin America and the commonwealth of Puerto Rico were administered the Rey–Osterrieth Complex Figure (ROCF) and the Hopkins Verbal Learning Test (HVLT-R). Two-thirds of the participants were women, and the average age was 53.5 ± 20.0 years. *Z*-scores were calculated for ROCF Copy and Memory scores and HVLT-R Total Recall, Delayed Recall, and Recognition scores, adjusting for age, age^2, sex, education, and interaction variables if significant for the given country. Each *Z*-score was converted to a percentile for each of the five subtest scores. Each participant was categorized based on his/her number of low scoring tests in specific percentile cutoff groups (25th, 16th, 10th, 5th, and 2nd). **Results:** Between 57.3% (El Salvador) and 64.6% (Bolivia) of the sample scored below the 25th percentile on at least one of the five scores. Between 27.1% (El Salvador) and 33.9% (Puerto Rico) scored below the 10th percentile on at least one of the five subtests. Between 5.9% (Chile, El Salvador, Peru) and 10.3% (Argentina) scored below the 2nd percentile on at least one of the five scores. **Conclusions:** Results are consistent with other studies that found that low scores are common when multiple neuropsychological outcomes are evaluated in healthy individuals. Clinicians should consider the higher probability of low scores when evaluating learning and memory using various sets of scores to reduce false-positive diagnoses of cognitive deficits.

Keywords: Neuropsychology, Neuropsychological test, Memory and learning test, Psychometrics, Diagnosis, Adult

INTRODUCTION

Learning and memory are cognitive functions necessary for independent daily living across the lifespan (Strauss et al., 2006). In particular, neuropsychological assessments of learning and memory aim to measure the cognitive abilities of registering, storing, and retrieving new information. Although multiple neuropsychological instruments are available to assess verbal and visual learning and memory processes [e.g., Rey Auditory Verbal Learning Test (Rey, 1958), Selective Reminding Test (Buschke, 1973; Buschke & Fuld, 1974), California Verbal Learning Test (Delis et al., 1987, 2000), Continuous Visual Memory Test (Trahan & Larrabee, 1988), or the Brief Visuospatial Memory Test–Revised (Benedict, 1997)], two of the most widely used instruments to measure learning and memory abilities worldwide are the Rey–Osterrieth Complex Figure (ROCF) Test (Rey, 1941) and the Hopkins Verbal

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Learning Test–Revised (HVLT-R; Benedict et al., 1998; Brandt & Benedict, 2001).

The ROCF uses an asymmetrical stimulus to measure cognitive performance via demonstrated abilities to recall visual information (Fastenau, 1996). Two conditions commonly utilized in the ROCF to evaluate memory abilities include the Immediate and Delayed Recall trials (Shin et al., 2006). The ROCF can be used to evaluate visual-based learning and memory in the context of dementia, traumatic brain injury, or other neurological disorders (e.g., schizophrenia, Huntington's disease, Korsakoff's syndrome; Shimamura et al., 1987; Silverstein et al., 1998; Tierney et al., 1994). Support for reliability and validity of the ROCF has been established in past research with a wide variety of samples (e.g., pediatric, adult, geriatric; Berry et al., 1991; Fastenau et al., 1999; Waber & Holmes, 1985). More specifically, the ROCF has received support for adequate inter-rater, alternate form, test-retest, and internal consistency reliability (Berry et al., 1991). Its notable psychometric support has contributed to its wide usage. The ROCF has been used worldwide in countries such as Argentina, Bolivia, Canada, Chile, Colombia, Cuba, Denmark, Ecuador, El Salvador, Guatemala, Honduras, Italy, Mexico, New Zealand, Paraguay, Peru, Spain, and the United States (e.g., Ardila & Rosselli, 1994; Fernando et al., 2003; Galindo & Cortes, 2003; Rivera et al., 2015a; Strauss et al., 2006; Vogel et al., 2012).

The HVLT-R is an auditory-based measure of learning and memory involving a list of words (Benedict et al., 1998; Brandt, 1991). Although the HVLT-R has six alternate forms, commonly utilized trials include the Hopkins Total Recall, Hopkins Delayed, and Hopkins Recognition forms (Benedict et al., 1998). The HVLT-R is also used to detect memory impairments associated with dementia, brain injury, HIV/AIDS, or other neurological disorders (Cysiqu et al., 2007; Kuslansky et al., 2004). Some research suggests it is best used for elderly people suspected of having dementia (Shapiro et al., 1999). It has received support for test–retest reliability, construct validity, and concurrent validity in past research with adults and geriatric populations (Benedict et al., 1998; Shapiro et al., 1999). The HVLT-R has also been used globally in countries such as Argentina, Brazil, Bolivia, Cameroon, Chile, China, Colombia, Cuba, El Salvador, Guatemala, Honduras, India, Mexico, Paraguay, Peru, South Africa, and the United States (Arango-Lasprilla et al., 2015; Benedict et al., 1998; Cysique et al., 2007; Hoare et al., 2012; Kanmogne et al., 2010; Rivera et al., 2015b; Yepthomi et al., 2006).

Although these measures were originally normed with English-speaking samples, normative data now exist for Spanish speaking adults for both the ROCF and HVLT-R (Arango-Lasprilla et al., 2015; Arango-Lasprilla & Rivera, 2015; Cherner et al., 2007; Rivera et al., 2015a, 2015b). Standardized normative data for diverse samples are necessary to validly assess memory outside of the United States and reduce the risk for misinterpretation of scores. For example, the risk of score misinterpretation is high when using an improper normative sample as a comparison. In addition to adequate, representative normative data, another important point of concern to reduce misinterpretation of scores on neuropsychological assessments is to determine the frequency and determinants of low test scores among healthy individuals.

Multivariate base rates (MVBRs) of low scores allow neuropsychologists to simultaneously interpret large amounts of data in different populations. When a battery of assessments is completed, chances increase dramatically for individuals to have one or more low scores on any individual test (Binder et al., 2009; Brooks et al., 2009, 2010, 2017). Thus, clinicians who are tasked with interpreting a large amount of clinical data must determine whether or not results reflect cognitive impairment (i.e., true positive) or a low score in an otherwise healthy individual (i.e., false positive). In addition, factors such as age, education, and gender tend to alter MVBRs and increase the prevalence of low scores among samples (Brooks & Iverson, 2010; Schretlen et al., 2008). Thus, MVBRs are an additional interpretation tool that can be used to improve the accuracy of identifying cognitive impairments and reduce misdiagnosing deficits where there are none. MVBRs have been developed for adult clinical samples to evaluate impairments such as amnestic mild cognitive impairment, Alzheimer's disease (Oltra–Cucarella et al., 2018), and mild neurocognitive disorder (Holdnack et al., 2017). Although MVBRs have been examined in English-speaking White adult populations (e.g., Brooks et al., 2010; Schretlen et al., 2008), to date no study has tested MVBRs with Spanish-speaking populations.

Demographic and culture-related factors have shown to influence low scores (e.g., Brook et al., 2010, 2017). As such, it is expected that MVBRs change from culture to culture. The present study aims to fill this gap in the literature by examining MVBRs among a Spanish-speaking adult Latino sample across 11 countries and the commonwealth of Puerto Rico who completed the ROCF and HVLT-R to assess their learning and memory capacities. Developing MVBRs among Spanish-speaking Latino individuals will allow for improved clinical interpretation of their neuropsychological performance to reduce the likelihood of over-diagnosing cognitive deficits. The goal of the present study is to develop and present the base rates of low scores on the ROCF and HVLT-R in a table that can facilitate interpretation of test scores to maintain an adequate false-positive rate when these two assessments are administered in a battery together (e.g., Brooks et al., 2010). It was hypothesized that the prevalence of low scores on the ROCF and HVLT-R, as determined using MVBRs, will exceed the expected prevalence rates found when interpreting a single score in isolation.

METHODS

Participants

The sample consisted of 5402 healthy individuals who were recruited from Argentina, Bolivia, Chile, Colombia, Cuba, El

Table 1. Sample distribution by country, age, education, and sex

		Age	Education	Sex	
				Male	Female
	n Total	Mean (SD)	Mean (SD)	*n* (%)	*n* (%)
Argentina	320	45.7 (19.5)	13.8 (4.5)	96 (30.0%)	224 (70.0%)
Bolivia	274	55.8 (22.0)	8.5 (4.4)	99 (36.1%)	175 (63.9%)
Chile	320	55.1 (19.6)	10.0 (5.2)	134 (41.9%)	186 (58.1%)
Colombia	1425	58.2 (19.6)	9.6 (5.3)	610 (42.8%)	815 (57.2%)
Cuba	306	53.0 (19.7)	11.7 (3.7)	142 (46.4%)	164 (53.6%)
El Salvador	257	56.0 (20.7)	8.9 (5.3)	100 (38.9%)	157 (61.1%)
Guatemala	214	53.2 (17.4)	11.5 (5.7)	95 (44.4%)	119 (55.6%)
Honduras	184	48.6 (18.8)	8.6 (5.6)	67 (36.4%)	117 (63.6%)
Mexico	1300	52.5 (20.5)	9.3 (4.7)	431 (33.2%)	869 (66.8%)
Paraguay	263	53.0 (14.8)	9.5 (4.4)	101 (38.4%)	162 (61.6%)
Peru	245	43.4 (20.6)	14.1 (3.7)	87 (35.5%)	158 (64.5%)
Puerto Rico	294	50.9 (18.5)	13.2 (4.2)	126 (42.9%)	168 (57.1%)

Salvador, Guatemala, Honduras, Mexico, Paraguay, Peru, and Puerto Rico. The demographic characteristics (i.e., age, education, and sex) by country can be found in Table 1.

To be eligible for study participation, individuals must have met the following requirements: (a) were between 18 and 95 years of age, (b) were born and currently live in the country where the protocol was conducted, (c) spoke Spanish as their native language, (d) had completed at least 1 year of formal education, (e) were able to read and write at the time of evaluation, (f) scored ≥23 on a Spanish version of the Mini-Mental State Examination (Folstein et al., 1975; Villaseñor-Cabrera et al., 2010), (g) scored ≤4 on a Spanish version of the Patient Health Questionnaire–9 (PHQ-9; Kroenke et al., 2001), and (h) scored ≥90 on the Barthel Index (Mahoney & Barthel, 1965).

A self-report questionnaire was administered to collect information about the participants' medical history and health status. Participants were determined to be ineligible if they reported or endorsed the following: (a) medical services received for diagnosed neurological or psychiatric conditions, (b) daily consumption and/or use of an illicit substance, (c) history of chronic disease (e.g., diabetes mellitus), (d) regular use of pain or other medications that may impact cognitive functioning, and/or (e) severe visual and/or hearing deficit. All participants were community volunteers who did not receive financial compensation for participation.

Measures

Rey–Osterrieth Complex Figure

The examiner administered the ROCF Figure A, which included the Copy portion, Immediate Recall after a 3-min delay, and then the Delayed Recall 30 min after the copy trial. The Spanish-language ROCF manual scoring guidelines were followed (Rey, 2009). The ROCF includes 18 elements, and the maximum score for each of the two tasks (Immediate and Delayed Recall) is 36. Two points are given when the element is correctly reproduced; 1 point is given when the reproduction is distorted, incomplete but placed properly, or complete but placed poorly; and .5 point is credited when the element is distorted or incomplete and placed poorly. A score of 0 is given when the element is absent or is not recognizable (Osterrieth, 1944). The ROCF is one of the 10 most commonly used tests by clinicians and researchers from 16 Latin American countries (Arango-Lasprilla et al., 2017).

Hopkins Verbal Learning Test–Revised

The HVLT-R list used in the present study was Form 5 because pilot testing supported that all words included on the list were known, used, and represented the same meaning in each participating country. Form 5 contains a list of 12 semantically related words in three categories (i.e., professions, sports, and vegetables). Three trials of successive learning are presented, in which the list of 12 words is read to the participant, and the correct answers of each learning trial are recorded. Total Recall is the sum of words recalled correctly in the three trials. After 20–25 min, the Delayed Recall and recognition phase occurs, where the subject is asked to recall all the words that they can remember from the initial list (Benedict et al., 1998; Brandt, 1991). HVLT-R has received support for adequate psychometric properties with Spanish-speaking populations (Guàrdia-Olmos et al., 2015b).

Procedure

The participants completed the ROCF and HVLT-R as part of a large battery of neuropsychological tests. For further information regarding the study's procedure, see Arango-Lasprilla and Rivera (2015) and Guàrdia-Olmos et al. (2015b). The

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University of Deusto's (Bilbao, Spain) Ethics Committee approved this study as the coordinating institution.

Statistical Analyses

Sample Size

The accuracy of the total sample size by country was established using classical estimation assuming infinite (i.e., very large) population sizes (Arrufat et al., 1999), where the case of maximum uncertainty was assumed ($\pi = 1 - \pi = .5$) with a confidence interval of 95%. The maximum error of sample sizes ranges from .063 to .049.

Demographic Variables' Effect on Neuropsychological Performance

The effects of demographic variables on ROCF (Immediate and Delayed Recall) and HVLT-R (Total Recall, Delayed Recall, and Recognition) scores were evaluated by means of multiple linear regression analyses. The full regression models included the following as predictors: age, age^2, level of education, sex, and all two-way interactions between these variables. Age was centered (= calendar age—mean age in the sample by country) before computing the squared age term to avoid multicollinearity (Kutner et al., 2005). Use of the squared age term allows for determination of potential linear or quadratic (e.g., curvilinear) effects of age on test scores. Education was dummy coded into a variable of 0 and 1: 1 if the participant had >12 years of education and 0 if the participants had 1–12 years of education (Guàrdia et al., 2005; Peña-Casanova et al., 2009), and Sex was dummy coded as *Male* = 1 and *Female* = 0. Independent variables that were not statistically significant in the multiple regression model were removed from the model, and the reduced model was fitted again. In the stepwise model-building procedure, no predictor was removed as long as it was also included in a higher order term in the model (Aiken et al., 1991). The full regression model can be formally described as: $y_i = \mathrm{B}_0 + \mathrm{B}_1 \cdot (Age - \overline{x}_{Age\ by\ country})_i + \mathrm{B}_2 \cdot (Age - \overline{x}_{Age\ by\ country})_i^2 + \mathrm{B}_3 \cdot (Level\ Education)_i + \mathrm{B}_4 \cdot Sex_i + \mathrm{B}_k \cdot Interactions_i + \varepsilon_i$. A Bonferroni-corrected alpha-level of .005 (=.05 / 9) was used. The model assumes that the residuals ε_i are normally distributed with mean 0 and variance σ_ε^2, i.e., $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$. For all multiple linear regression models, the following assumptions were evaluated: (a) multicollinearity [evaluated by computing the Variance Inflation Factor (VIF), which should not exceed 10, and by computing the collinearity tolerance values, which should not exceed 1], (b) homoscedasticity (evaluated by grouping the participants into quartiles of the predicted test scores and applying Levene's test on the residuals), (c) normality of the standardized residuals (evaluated by conducting the Kolmogorov–Smirnov test), and (d) the existence of influential values (evaluated by computing the maximum Cook's distance).

Calculation of Adjusted Z-score

Adjusted *Z*-scores for each raw score were calculated using the information provided in each final regression model in a three-step procedure (Rivera & Arango-Lasprilla, 2017; Van Der Elst et al., 2006a, 2006b): (1) The expected test score ($\widehat{Y}_i$) is computed based on the fixed effect parameter estimated of the established final regression model: $\widehat{Y}_i = B_0 + B_1X_{1i} + B_2X_{2i} + \ldots + B_KX_{Ki}$. (2) To obtain the residual value e_i, a subtraction between the raw score of the neuropsychological test Y_i and the predicted value ($\widehat{Y}_i$) previously calculated was performed as shown in the following formula: $e_i = Y_i - \widehat{Y}_i$. (3) Using the residual standard deviation (SD_e) value provided by the regression model, residuals were standardized: $z_i = e_i / SD_e$. This three-step process was applied to each score (ROCF Immediate Recall, ROCF Delayed Recall, HVLT-R Total Recall, HVLT-R Delayed Recall, and HVLT-R Recognition) separately for each country.

Multivariate Base Rates

The exact percentile corresponding to the *Z*-score previously calculated was obtained using the standard normal cumulative distribution function (if the model assumption of normality of the residuals was met in the normative sample), or via the empirical cumulative distribution function of the standardized residuals (if the standardized residuals were not normally distributed in the normative sample). Percentiles that are routinely used in clinical practice or research as indicator of low performance were analyzed in this study: (a) below the 25th percentile, (b) below the 16th percentile, (c) below the 10th percentile, (d) below the 5th percentile, and (e) below the 2nd percentile.

The prevalence below each of these percentiles was calculated. This base-rate analysis was calculated to involve examination of learning and memory performance on the five *Z*-scores (ROCF Immediate Recall, ROCF Delayed Recall, HVLT-R Total Recall, HVLT-R Delayed Recall, and HVLT-R Recognition) simultaneously, not each score in isolation. All the analyses were performed using SPSS version 23 (IBM Corp., 2015).

RESULTS

The assumptions of multiple linear regression analysis were largely met for all final models. There was no multicollinearity (i.e., the VIF values in all final models did not exceed 3.143, and thus well below the threshold value of 10 that is indicative of multicollinearity; collinearity tolerance values did not exceed the value of 1) nor influential cases (i.e., the maximum Cook's distance value was .493). Levene's test suggested homoscedasticity in all countries except for the models of Argentina and Paraguay in HVLT-R Delayed Recall, and for Paraguay in HVLT-R Total Recall. In ROCF Immediate and Delayed Recall, homoscedasticity

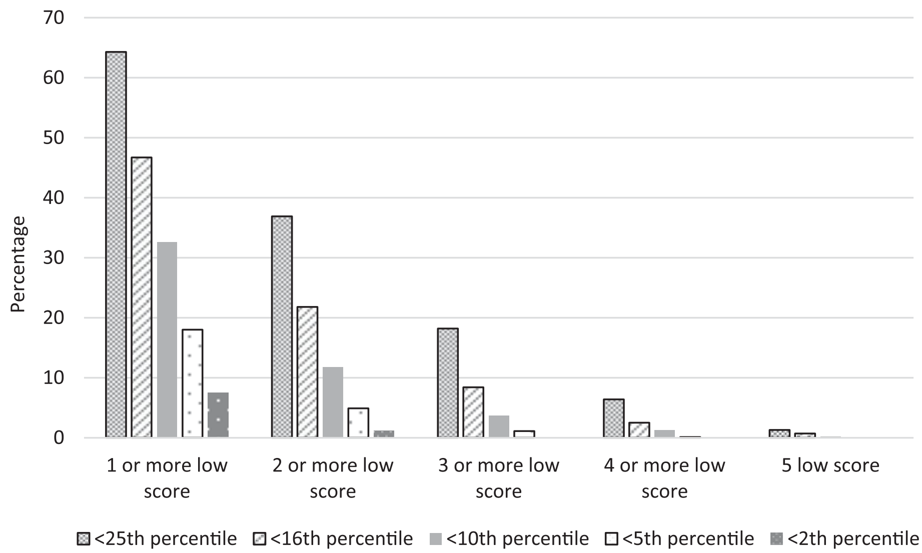

Fig. 1. Cumulative proportion of Colombian adults with the specified number of adjusted learning and memory low scores below the specified percentile cutoff.

was not met in all countries except for Paraguay in ROCF Immediate Recall, and for Chile, Cuba, El Salvador, Guatemala, Honduras, Mexico, Peru, and Puerto Rico in ROCF Delayed Recall. Standardized residuals of the models were normally distributed in all countries (as evaluated with the Kolmogorov–Smirnov test) except for the HVLT-R Recognition and the ROCF Immediate Recall in Argentina, Chile, Colombia, Cuba, Guatemala, Honduras, Mexico, Peru, and Puerto Rico.

Table 2 shows the final regression models for each score (ROCF Immediate Recall, ROCF Delayed Recall, HVLT-R Total Recall, HVLT-R Delayed Recall, and HVLT-R Recognition) and country. The amount of variance explained in scores ranged from 1.8% (in Cuba on the HVLT-R Recognition score) to 44.9% (in Paraguay on the HVLT-R Delayed Recall).

The base rates of low test scores on the memory and learning performance are presented in Table 3. Between 57.3% (El Salvador) and 64.6% (Bolivia) of the sample have at least one of the five scores below the 25th percentile, and between 36.3% (Paraguay) and 49.3% (Bolivian and Cuba) scored below the 16th percentile on one or more scores. Moreover, between 27.1% (El Salvador) and 33.9% (Puerto Rico) scored below the 10th percentile on at least one of the five scores, and between 24.8% (Paraguay) and 33.9% (Puerto Rico) scored below the 5th percentile on one or more scores. Finally, between 5.9% (Chile, El Salvador, and Peru) and 10.3% (Argentina) scored below the 2nd percentile on at least one of the five scores.

An example will be provided to facilitate the interpretation of Table 3. For example, in Colombia, 64.3% of the sample have at least one of the five scores below the 25th percentile, 46.7% below the 16th percentile, 32.6% below the 10th percentile, 18% below the 5th percentile, and 7.5% below the 2nd percentile. The same results are represented visually in Figure 1.

Additionally, the reader can find in Appendices A1–A12 in the Supplementary Material the base rates of low test scores on the memory and learning performance for each country divided by age, sex, and education.

DISCUSSION

The recent collection and publication of normative data for the ROCF and HVLT-R based on $N = 5402$ Hispanic adults across 11 countries and Puerto Rico represent a leap forward for neuropsychological assessments with Spanish-speaking populations. Without adequate normative data to use with adults from Argentina, Bolivia, Chile, Colombia, Cuba, El Salvador, Guatemala, Honduras, Mexico, Paraguay, Peru, and Puerto Rico, it is likely that memory impairments have been over-diagnosed by clinicians at an alarming rate (e.g., Cherner et al., 2007). The presentation of MVBRs for these Spanish-based normative scores represents another step forward in the interpretation of these data and the ethical progression towards lowering the rates of misdiagnosed memory impairments.

The results of the present study supported our hypothesis. When considering MVBRs for the five scores from the ROCF and HVLT-R, the obtained prevalence rates of low scores far exceeded the theoretical prevalence rates based on a Gaussian distribution for a single score. For example, having one or more memory scores <16th percentile (i.e., one standard deviation below the mean) occurred in 27–34% of Spanish-speaking adults, which is much higher than the theoretical base rate of <16%. If a clinician wanted to maintain a prevalence rate of <16% for low scores when considering MVBRs, then this would be achieved by interpreting three or more scores <16th percentile (i.e., found in 7.3–12.5% across the countries). One or more “impaired” memory scores, when impaired is defined as a score falling below

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Table 2. Beta coefficients and R^2 for each score and country

Score		Argentina	Bolivia	Chile	Colombia	Cuba	El Salvador	Guatemala	Honduras	Mexico	Paraguay	Peru	Puerto Rico
HVLT-R Total Recall	Intercept	22.937	18.311	19.303	19.075	20.106	16.685	20.836	16.192	20.696	14.709	20.612	22.007
	Age	−.070	−.112	−.132	−.122	−.115	−.112	−.096	−.100	−.122	−.112	−.095	−.161
	Age^2	—	—	—	−.001	—	—	—	—	−.002	—	—	—
	Education	2.764	3.264	4.140	3.042	2.830	5.287	2.815	3.762	2.229	5.685	1.999	—
	Sex	—	—	—	−.801	—	—	−2.552	—	—	—	—	—
	R^2	.183	.323	.360	.308	.277	.331	.225	.299	.259	.396	.221	.344
HVLT-R Delayed Recall	Intercept	7.750	6.106	7.327	6.203	6.676	5.233	7.187	5.227	7.089	4.013	6.502	7.865
	Age	−.042	−.064	−.073	−.060	−.044	−.059	−.047	−.051	−.061	−.054	−.048	−.086
	Age^2	—	—	−.001	−.001	—	—	—	—	−.001	—	—	—
	Education	1.515	—	1.368	1.322	1.434	1.995	1.257	1.844	0.891	2.872	1.192	—
	Sex	—	—	—	—	—	—	−1.324	—	—	—	—	−.800
	R^2	.258	.253	.344	.253	.202	.313	.177	.255	.252	.449	.281	.345
HVLT-R Recognition	Intercept	11.554	10.763	11.198	10.747	10.877	—	11.099	—	11.011	10.838	11.143	11.157
	Age	−.010	−.019	−.030	−.025	−.013	—	−.021	—	−.021	−.036	−.012	−.030
	Age^2	—	—	−.001	.001	—	—	—	—	.000	−.001	—	—
	Education	—	—	—	.356	—	—	—	—	.578	.789	—	—
	Sex	—	—	—	—	—	—	−0.705	—	—	—	—	−.673
	Age^2 × Edu	—	—	—	—	—	—	—	—	−.001	—	—	—
	R^2	.044	.062	.140	.082	.018	—	.076	—	.087	.251	.028	.118
ROFC Immediate Recall	Intercept	34.139	23.917	28.130	28.004	32.578	22.667	29.046	25.811	29.759	29.136	33.973	31.884
	Age	1.266	−.152	−.182	−.223	−.185	−.121	4.534	−.148	−.076	−.126	−.106	−.151
	Age^2	—	—	—	−0.003	−0.004	—	—	—	—	−0.003	−0.002	−0.003
	Education	—	4.820	—	4.013	2.866	8.695	—	5.699	1.862	3.269	2.194	1.983
	Sex	—	2.977	—	—	—	—	—	—	1.329	.078		
	Age × Edu	—	—	—	.060	.141	—	—	—	—	—		
	R^2	.056	.296	.183	.276	.265	.245	.107	.210	.103	.373	.361	.288
ROCF Delayed Recall	Intercept	19.983	14.035	13.866	13.085	21.071	12.850	15.246	11.922	16.357	15.977	17.914	17.693
	Age	−.152	−.169	−.175	−.204	−.276	−.188	−.155	−.159	−.150	−.104	−.195	−.279
	Age^2	—	—	—	—	−0.005	—	—	—	—	—	—	
	Education	3.765	3.744	3.009	4.158	−0.705	8.005	3.687	6.148	2.612	3.569	3.404	2.520
	Sex	2.275	—	—	1.768	—	—	—	4.049	2.173	—	—	—
	Age × Edu	—	—	—	—	.232	—	—	—	—	—	—	—
	Age^2 × Edu	—	—	—	—	.010	—	—	—	—	—	—	—
	R^2	.273	.260	.227	.356	.302	.409	.200	.371	.231	.237	.360	.398

Table 3. Cumulative proportion of adults with the specified number of adjusted learning and memory low scores below the specified percentile cutoff by country

Learning & Memory		All countries	Argentina	Bolivia	Chile	Colombia	Cuba	El Salvador	Honduras	Guatemala	Mexico	Paraguay	Peru	Puerto Rico
<25th percentile	No low scores	38.4%	40.3%	35.4%	41.9%	35.7%	36.9%	42.7%	39.1%	41.2%	39.2%	40.8%	38.1%	38.1%
	One or more low scores	61.6%	59.7%	64.6%	58.1%	64.3%	63.1%	57.3%	60.9%	58.8%	60.8%	59.2%	61.9%	61.9%
	Two or more low scores	35.6%	34.1%	37.2%	36.6%	36.9%	32.0%	34.1%	38.0%	35.1%	35.7%	31.3%	35.1%	37.0%
	Three or more low scores	17.9%	20.6%	17.9%	20.9%	18.2%	13.4%	19.6%	21.2%	15.2%	16.7%	19.8%	19.2%	15.9%
	Four or more low scores	7.1%	9.7%	5.1%	9.4%	6.4%	5.2%	7.5%	8.2%	7.6%	7.3%	8.0%	6.7%	5.5%
	Five low scores	1.7%	4.1%	—	.3%	1.3%	.3%	1.6%	2.2%	3.3%	2.1%	2.7%	1.3%	2.1%
<16th percentile	No low scores	55.6%	58.4%	50.7%	58.8%	53.3%	50.7%	59.2%	59.8%	58.3%	55.4%	63.7%	57.7%	54.7%
	One or more low scores	44.4%	41.6%	49.3%	41.3%	46.7%	49.3%	40.8%	40.2%	41.7%	44.6%	36.3%	42.3%	45.3%
	Two or more low scores	21.8%	20.3%	24.1%	25.3%	21.8%	21.6%	19.6%	23.4%	22.3%	21.3%	19.1%	22.2%	22.5%
	Three or more low scores	9.0%	11.3%	8.8%	10.9%	8.4%	7.2%	9.4%	12.5%	9.0%	9.0%	9.2%	7.9%	7.3%
	Four or more low scores	2.9%	4.1%	1.1%	2.2%	2.5%	1.3%	2.4%	4.3%	4.7%	4.0%	2.7%	.8%	2.8%
	Five low scores	.7%	.9%	—	—	.7%	.3%	.8%	.5%	1.4%	1.2%	0.8%	—	.7%
<10th percentile	No low scores	69.1%	71.6%	66.8%	71.6%	67.4%	68.0%	72.9%	72.3%	71.1%	68.3%	75.2%	69.5%	66.1%
	One or more low scores	30.9%	28.4%	33.2%	28.4%	32.6%	32.0%	27.1%	27.7%	28.9%	31.7%	24.8%	30.5%	33.9%
	Two or more low scores	12.5%	12.5%	12.8%	16.6%	11.8%	10.1%	10.2%	12.5%	14.2%	12.3%	12.2%	15.5%	13.8%
	Three or more low scores	4.0%	5.6%	4.4%	4.1%	3.7%	2.3%	3.9%	3.8%	4.3%	4.6%	3.4%	4.6%	2.4%
	Four or more low scores	1.1%	1.6%	—	.3%	1.3%	.7%	.8%	2.2%	1.4%	1.3%	.8%	.4%	.7%
	Five low scores	.3%	.3%	—	—	.2%	—	—	.5%	.5%	.6%	.4%	—	.3%
<5th percentile	No low scores	82.5%	80.6%	79.9%	84.1%	82.0%	84.3%	83.5%	86.4%	83.4%	82.0%	86.3%	82.0%	80.6%
	One or more low scores	17.5%	19.4%	20.1%	15.9%	18.0%	15.7%	16.5%	13.6%	16.6%	18.0%	13.7%	18.0%	19.4%
	Two or more low scores	5.1%	5.6%	5.5%	4.7%	4.9%	2.9%	4.7%	5.4%	4.3%	5.6%	6.9%	5.0%	4.5%
	Three or more low scores	1.3%	2.2%	.7%	1.3%	1.1%	.7%	1.6%	1.1%	4.3%	1.4%	.8%	1.7%	.3%
	Four or more low scores	.1%	—	—	—	.1%	—	.4%	—	.5%	.2%	—	.4%	—
	Five low scores	—	—	—	—	—	—	—	—	—	.1%	—	—	—
<2th percentile	No low scores	92.1%	89.7%	91.6%	94.1%	92.5%	93.5%	94.1%	92.4%	91.0%	90.7%	92.7%	94.1%	91.7%
	One or more low scores	7.9%	10.3%	8.4%	5.9%	7.5%	6.5%	5.9%	7.6%	9.0%	9.3%	7.3%	5.9%	8.3%
	Two or more low scores	1.4%	2.2%	.7%	1.3%	1.2%	1.0%	—	2.2%	1.9%	1.7%	2.7%	.8%	.7%
	Three or more low scores	.2%	.3%	—	—	.1%	.3%	—	—	.5%	.2%	—	.4%	—
	Four or more low scores	—	—	—	—	.1%	—	—	—	—	—	—	—	—
	Five low scores	—	—	—	—	—	—	—	—	—	—	—	—	—

the 2nd percentile (more than two standard deviations below the mean), was found in 6–10% of Spanish-speaking adults. Again, maintaining the desired <2% prevalence rate could be achieved by having two or more scores <2nd percentile, rather than just one. A clear advantage of using MVBRs when interpreting multiple scores simultaneously is that they adjust for the inflation of prevalence rates that exceed conventional expectations when only interpreting a single score (Binder et al., 2009; Brooks et al., 2009, 2010; Schretlen et al., 2008).

The results of this study from a large Spanish-speaking population are consistent with the literature on MVBRs of memory scores using North American English-speaking samples. Prior studies considering English-speaking samples of adults (Brooks et al., 2011, 2013) and older adults (Brooks et al., 2008, 2009, 2011, 2013) have also shown high rates of low memory scores when multiple scores are considered simultaneously. On the WMS-IV (Wechsler, 2009) in adults aged 18–69 years, having one or more low scores (≤16th percentile) was found in 29% of the sample when considering four primary indexes and in 51% when considering six scores from the primary subtests. In a large sample of older adults aged 55–87 years, having one or more low scores (≤16th percentile) on the WMS-IV was found in 64% of individuals when considering eight scores from primary memory subtests. And finally, in another large sample of older adults aged 55–79 years, having one or more low scores (≤16th percentile) on the NAB Memory Module was found in 55% when considering the 10 primary scores. Clearly, having low scores is not necessarily atypical, and the base rates of low scores increase as the number of scores increases; therefore, adjusting interpretation using MVBRs will help clinicians to minimize misdiagnosis (Brooks et al., 2007, 2009).

The base rates of low memory scores did not differ across the broad levels of education in this Spanish-speaking sample. Although prior MVBR studies with English-speaking samples have often shown that base rates are higher among those with fewer years of education—for example, one or more low WMS-IV scores (≤16th percentile) was found in 84% of adults with eight or fewer years of education but in only 37% with 16 or more years of education (Brooks et al., 2013)—those with 1–12 years of schooling had roughly equivalent rates of low memory scores compared to those with more than 12 years of education in the present study. One potential reason for the absence of differences in the present study was that the standard scores were adjusted using the regression for education (in addition to age and sex). When scores are adjusted for education, different base rates of low scores across education levels become minimal and nonsignificant (Brooks et al., 2013).

These results should be interpreted in the light of the following limitations: (a) In this study, the MVBRs were calculated for two of the most commonly used tests to measure learning and memory processes; however, we do not know if these results are similar or different when other memory tests are used. (b) The number of tests used in the present study was five, and thus it is possible that to the extent that more scores from other memory tests were included, these results could even be lower. (c) The present study was conducted with a large Spanish-speaking population from 11 Latin American countries and Puerto Rico, and for this reason it is not possible to generalize these results to those countries outside of the present sample or those whose language is not Spanish (e.g., Brazil). (d) It is possible that the low scores found in this study could be explained by some variables that were not measured or not considered when carrying out the study, such level of bilingualism and the quality of education, among others. (e) Education was used as a dummy coded, dichotomous variable (i.e., 12 or >12 years of education), and as such, future studies should include education as a continuous variable. Finally, (f) the sample was not stratified by intellectual level, which has been shown to be associated with different base rates of low scores on cognitive measures (Brooks et al., 2008, 2009, 2011, 2013; Guàrdia-Olmos et al., 2015a; Rivera & Arango-Lasprilla, 2017). Future research will consider MVBRs in Latino samples with varying levels of intellectual abilities.

Having access to normative data from Argentina, Bolivia, Chile, Colombia, Cuba, El Salvador, Guatemala, Honduras, Mexico, Paraguay, Peru, and Puerto Rico is an advancement for neuropsychologists who assess Spanish-speaking adults. Knowing the MVBRs of commonly used memory scores in this large sample will improve the interpretation of these normative data. Consistent with the literature with English-speaking adults, it is also common for Spanish-speaking adults to have higher rates of low memory scores when multiple scores are being interpreted. Thus, the presence of low scores may not necessarily indicate an impairment. MVBRs are an interpretive tool that clinicians should not ignore, but instead should use judiciously and with clinical judgment.

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CONFLICT OF INTEREST

Authors declare no conflicts of interest except Brian Brooks.

CONFLICT STATEMENT FOR BRIAN BROOKS

Dr. Brooks reports the following conflicts of interest: co-author of the Child and Adolescent Memory Profile (ChAMP, Sherman and Brooks, 2015, PAR Inc.), Memory Validity Profile (MVP; Sherman and Brooks, 2015, PAR Inc.), and Multidimensional Everyday Memory Ratings for Youth (MEMRY, Sherman and Brooks, 2017, PAR Inc.), and he receives royalties for the sales of these tests; coeditor of the Pediatric Forensic Neuropsychology textbook (2012, Oxford University Press) and receives royalties for the sales of this book; previously been provided with free test credits from CNS Vital Signs as an in-kind support for his research.

SUPPLEMENTARY MATERIALS

To view supplementary material for this article, please visit https://doi.org/10.1017/S135561771900050X.

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