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Demographically-adjusted norms for the Grooved Pegboard and Finger Tapping tests in Spanish-speaking adults: Results from the Neuropsychological Norms for the U.S.-Mexico Border Region in Spanish (NP-NUMBRS) Project

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ABSTRACT

Objective: We developed demographically-corrected norms for Spanish-speakers from the U.S.-Mexico border regions of California and Arizona on two tests of motor skills - the Grooved Pegboard Test (Pegboard) and Finger Tapping Test (Tapping) - as part of a larger normative effort.

Method: Participants were native Spanish-speakers from the Neuropsychological Norms for the U.S.-Mexico Border Region in Spanish (NP-NUMBRS) Project (Pegboard: $N = 254$; Tapping: $N = 183$; age: 19–60 years; education: 0–20 years; 59% women). We examined the association of demographics (age, education and gender) with raw scores. Raw test scores were then converted to demographically-corrected T-scores via fractional polynomial equations. We also examined rates of impairment (T-score < 40) based on the current norms and on previously published norms for English-speaking non-Hispanic Whites and Blacks.

Results: Having more years of education was associated with better raw test score performance on both tests ($p < .001$), and increased age was associated with worse performance on Pegboard ($p < .001$). Men outperformed women on Tapping, and older age was associated with lower raw scores in men only on the Tapping non-dominant hand trial ($p = .02$). The normed T-scores were confirmed to be normally distributed and free from demographic influences, and resulted in expected rates of impairment. Applying existing norms for English-speaking non-Hispanic Whites and Blacks to the raw scores of Spanish-speakers generally yielded lower than expected impairment rates (2–13%), with

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one exception: non-dominant Pegboard, for which non-Hispanic White norms overestimated impairment (23%).

Conclusions: Present findings underscore the importance of appropriate, population-specific normative data, even for tests of motor ability.

Introduction

Assessment of fine motor functioning is usually part of comprehensive neuropsychological evaluations. The characterization of motor skills provides information that can be relevant to functional outcomes (Anstey et al., 2001; Haaland et al., 1994). In addition, it often plays an important role in making inferences about central nervous system focal lesion lateralization and the functional integrity of each cerebral hemisphere (Goldstein, 1974; Reitan, 1966). Deficits in this domain have been implicated in a host of neurological conditions, including traumatic brain injury, stroke, epilepsy, multiple sclerosis, HIV infection, movement disorders, and others (Arneson et al., 2018; Heaton et al., 2015; Hernandez, et al., 2002; Johansson & Häger, 2019; Li et al., 2003; Montoya et al., 2019; Rivera Mindt et al., 2003). While several motor tasks exist, two of the most commonly administered measures include the Finger Tapping Test (Halstead, 1947; Reitan & Wolfson, 1993; Spreen & Strauss, 1998), and the Grooved Pegboard Test (Klove, 1963).

Demographic differences (i.e. age, education, gender, race/ethnicity) can influence neuropsychological test performance and need to be accounted for in determining normal expectations and criteria for classifying disease-related impairment (Alley et al., 2007; Brewster et al., 2014; Díaz-Venegas, et al., 2016; Flores et al., 2017; Heaton, Marcotte, et al., 2004; Heaton, Ryan, & Grant, 2009; Nell, 2000; Pontón et al., 1996; Puente & Agranovich, 2003; Rivera Mindt, Byrd, Saez, & Manly, 2010; Rosselli & Ardila, 2003). Normative data that correct for these effects decrease the likelihood of misclassifying impairment in groups and individuals with diverse demographic and background characteristics. Heaton, Miller, Taylor & Grant (2004) have published normative data on the Finger Tapping and Grooved Pegboard tests for English-speaking non-Hispanic White (NHW) and non-Hispanic African American/Black (NHB) populations in the U.S. In both of these racial groups, performance on Finger Tapping was driven in large part by age and sex differences, with moderate education effects. Younger age and more years of education were associated with better performance, and men outperformed women on this test (Heaton, Miller, et al., 2004). Performance on the Grooved Pegboard was most affected by age, with a much lower influence of sex and education (Heaton, Miller, et al., 2004). Despite being comparable on age, education, and gender, NHWs performed better than NHBs on both Finger Tapping and Grooved Pegboard tests, raising concerns that similar findings might emerge in other U.S. minority groups.

Members of ethnic/racial groups who value speed, competitiveness, and success might perform better on timed assessments, compared to those from cultures that value accuracy over speed (Heaton et al., 2009; Mulenga et al., 2001; Nell, 2000; Puente & Agranovich, 2003). Evidence suggests Spanish-speakers perform differently

than English-speaking NHWs on many neuropsychological tests, including those involving both verbal and non-verbal skills (Arango-Lasprilla et al., 2015; Ardila, 2005; Ardila & Moreno, 2001; Arnold et al., 1994; Artiola i Fortuny et al., 1998; Benson et al., 2014; Boone et al., 2007; Buré-Reyes et al., 2013; Casaletto et al., 2015; Cherner et al., 2007; Flores et al., 2017; Gasquoine, 2001; Matute et al., 2000; Mulenga et al., 2001; O'Bryant et al., 2018; Ojeda, 2010; Ostrosky-Solis, Efron, & Yund, 1991; Polubinski & Melamed, 1986; Pontón et al., 1996; Puente & Salazar, 1998; Rivera Mindt et al., 2010; Rosselli, Ardila, Bateman, & Guzman, 2001; Rosselli & Ardila, 2003; Wang et al., 2015). Although Rosselli and colleagues (2001) published norms for Spanish-speaking Colombian children on Finger Tapping and Grooved Pegboard tests, normative data on motor tests for Spanish-speakers living in the U.S. are rather limited. Previous studies (Pontón et al., 1996) have generated normative data for Spanish-speakers living in the U.S. on the Pin Test, which is similar to the Grooved Pegboard Test, but to our knowledge normative data have not been generated for this population on the Finger Tapping or Grooved Pegboard tests. Similarly, the extant literature has not specifically investigated the influence of demographic factors such as age, education and gender on fine motor functioning among Spanish-speakers.

Given the limitations to existing normative datasets for linguistic minorities, this study aimed to develop and provide demographically-corrected norms for the Finger Tapping and Grooved Pegboard tests among U.S.-dwelling native Spanish-speakers who reside in the U.S.-Mexico border regions of California and Arizona. In addition, this study aimed to investigate the impact of applying existing norms for English-speaking NHWs and NHBs on the classification of impairment on fine motor tests among these Spanish-speakers.

Methods

Participants

Participants were part of a larger normative effort called the Neuropsychological Norms for the U.S.-Mexico Border Region in Spanish (NP-NUMBRS) project. This norming project combined participants from two cohorts recruited at different timepoints to increase the size of the normative sample. Participants from the first cohort (Cohort 1, $N = 183$) were recruited between 1998 and 2000 from or near the regions of Tucson, Arizona ($n = 102$) and San Diego, California ($n = 81$). Participants from the second cohort (Cohort 2, $N = 71$) were recruited between 2006-2009 from or near San Diego only. Two-hundred and fifty-four adults completed the Grooved Pegboard Test (all participants from both cohorts) and a subset of 183 participants completed the Finger Tapping Test (all from Cohort 1) as part of a comprehensive neuropsychological battery. Multiple papers in this issue on the NP-NUMBRS project present demographically-corrected norms for all cognitive domains in this battery, i.e. verbal fluency (Marquine, Morlett Paredes, et al., 2020), speed of information processing (Rivera Mindt, Marquine, Aghvinian, Scott, et al., 2020; Suárez, Díaz-Santos, et al., 2020), attention/working memory (Gooding et al., 2020), executive functioning (Marquine, Yassai-Gonzalez, et al., 2020; Morlett Paredes, Carrasco, et al., 2020; Suárez, Díaz-Santos, et al., 2020), learning and memory (Díaz-Santos et al., 2020), visuospatial skills (Scott et al., 2020), and fine motor skills, which is the focus of the current report. For additional information on this NP-NUMBRS project and the state of

norms for Spanish-speakers in this U.S.-Mexico border region, see the introduction paper (Marquine, Rivera Mindt, et al., 2020) and review paper (Morlett Paredes, Gooding, et al., 2020) in this issue. Finally, a paper by Kamalyan et al. (2020) begins to address the validity of the current norms for most tests in the NP-NUMBRS battery (including the Pegboard) for detecting central nervous system disorders, by applying the norms to test results of Spanish-speaking, U.S.-Mexico border region residents with HIV infection.

All participants resided in the U.S. at least part of the time, had Spanish as their native and currently dominant language, and were tested in Spanish by bilingual (Spanish-English) trained psychometrists. Motor test formats were not changed from the English versions, and translations of instructions were conducted in a manner consistent with published guidelines (Hambleton, Merenda, & Spielberger, 2005; International Test Commission, 2005, 2017; van de Vijver & Hambleton, 1996); instructions for both measures were back-translated and examined for fidelity with the English versions (see *Appendices A* and *B* for test administration instructions in Spanish). Potential participants for both cohorts were screened based on similar inclusion and exclusion criteria using structured interviews. Participants were excluded for any condition or illness that may influence test performance, such as a central nervous system disorder, medical condition, serious psychiatric condition, or peripheral injury. Less serious conditions or disabilities were reviewed on a case-by-case basis by senior investigators. Although participants with reading glasses were told to bring them on the day of testing, there was no vision test performed prior to testing and visual acuity was not specifically tested. For additional details on study recruitment, participants, procedures, and data collection, see Cherner*, Marquine*, et al. (2020).

Motor assessments

The Finger Tapping Test is a measure of simple motor speed. Participants are instructed to place the index finger of one hand on a counting device similar to a telegraph key and are asked to use it to tap as many times as possible in 10-second trials. The participants perform five consecutive 10-second trials, first with their dominant hand, and then their nondominant hand. A total score generated for each hand is the mean of 5 consecutive trials (i.e., five trials within a 5-point range). See Reitan & Wolfson (1993) for more details on test administration, including the addition of more trials in the case of excessive variability across the first 5 trials.

The Grooved Pegboard Test measures manipulative dexterity and perceptual-motor speed. The pegboard contains 25 grooved holes (5 rows with 5 holes each) that match the grooves of the pegs. The grooved holes on the pegboard are randomly oriented, such that the pegs must be rotated to fit into each groove. The participants are instructed to use only one hand (first their dominant hand, then their non-dominant hand) to insert all of the 25 pegs in rows from top to bottom as fast as they can by matching the groove of the pegs with grooved holes in the pegboard. Scores are generated for the time of each trial, the number of pegs that are correctly inserted (25 if completed), and the number of pegs unintentionally dropped for each trial. See the Trites (1977) and Lafayette Instrument Company (2002) manuals for more detail on test administration.

Demographically-corrected T-scores ($M = 50$, $SD = 10$) are reported for the following scores:

Grooved Pegboard Dominant Hand Total Score: Total time to completion (in seconds) using only the dominant hand.

Grooved Pegboard Non-dominant Hand Total Score: Total time to completion (in seconds) using only the non-dominant hand.

Finger Tapping Dominant Hand Total Score: Mean number of taps produced in 5, 10-second trials using only the index finger on the dominant hand.

Finger Tapping Non-dominant Hand Total Score: Mean number of taps produced in 5, 10-second trials using only the index finger on the non-dominant hand.

Statistical analyses

The distribution of raw scores was examined via Shapiro-Wilk tests. The univariable associations between demographic characteristics (age, education, and sex) and raw test scores were examined with Pearson product moment correlation coefficients (or Spearman ρ) for age and education, and independent sample *t*-tests or Wilcoxon rank-sum tests for sex. The interactive effect of demographic variables on raw test scores was investigated via separate linear regression models with terms for the two-way interaction of demographics (i.e., age X education, age X sex, education X sex).

Normed scores were calculated by first converting raw scores to normalized scaled scores (SS ; mean = 10, $SD = 3$). Scaled scores were then converted to age-, education-, and sex-corrected T-scores via a series of fractional polynomial equations, which allowed for the consideration of linear and nonlinear effects of demographics factors. Please see Cherner*, Marquine*, et al. (2020) for further details on norming procedures. We examined the distribution of the resulting T-scores via Shapiro-Wilk tests and their association with demographic factors via Pearson product moment correlation coefficients for age and education, and an independent sample *t*-test for sex. We also compared the resulting T-scores by cohort and site via independent sample-tests. Lastly, we calculated T-scores based on published norms for English-speaking NHWs and NHBs (Heaton, Miller, et al., 2004) on the present sample, and computed rates of impairment (T-scores < 40) utilizing both the published norms and the current norms for Spanish-speakers. McNemar's tests were then used to compare rates of impairment applying our newly-developed Spanish-speaking norms and published norms for English-speaking NHWs and NHBs (Heaton, Miller, et al., 2004).

Results

Demographic characteristics of the norming sample

Demographic characteristics of the norming sample with data on the Grooved Pegboard and the Finger Tapping tests are summarized in Table 1a. The sample was comprised of adults ages 19 to 60, who had an average education of less than high school, and with a little over half being female. There were no significant differences on age ($p = .12$), education ($p = .40$) or gender ($p = .97$) between participants who

Table 1a. Demographic characteristics of the normative sample for the Grooved Pegboard test and Finger Tapping test.

	Grooved Pegboard (N = 254)	Finger Tapping (N = 183)
Age (years),		
M (SD)	37.32 (10.24)	37.15 (9.58)
Range	19–60	20–55
Education (years),		
M (SD)	10.67 (4.34)	9.93 (4.20)
Range	0–20	0–20
N (%)		
≤6	22.84% (58)	27.32% (50)
7–10	22.05% (56)	25.14% (46)
11–12	25.20% (64)	24.59% (45)
≥13	29.92% (76)	22.95% (42)
% Female	58.66%	57.92%

Table 1b. Demographic characteristics of the normative sample for the Grooved Pegboard Test stratified by years of education (N = 254).

	≤6 (n = 58)	7–10 (n = 56)	11–12 (n = 64)	≥13 (n = 76)
Age (years), M (SD)	39.71 (9.86)	36.95 (9.54)	35.14 (10.34)	37.61 (10.69)
Education (years), M (SD)	4.72 (1.55)	8.59 (0.91)	11.81 (0.39)	15.79 (1.67)
% Female	62.07%	55.36%	65.53%	52.63%

Table 1c. Demographic characteristics of the normative sample for the Finger Tapping Test stratified by years of education (N = 183).

	≤6 (n = 50)	7–10 (n = 46)	11–12 (n = 45)	≥13 (n = 42)
Age (years), M (SD)	38.38 (9.41)	36.74 (9.35)	35.04 (9.82)	38.40 (9.68)
Education (years), M (SD)	4.68 (1.52)	8.61 (0.86)	11.84 (0.37)	15.57 (1.58)
% Female	62.00%	56.52%	62.22%	50.00%

completed both tests and those who completed only the Grooved Pegboard test. [Tables 1b and 1c](#) show demographic characteristics stratified by education group (≤6 years, 7–10 years, 11–12 years, and ≥13 years of education) for the Pegboard and Tapping tests, respectively. [Table 2](#) includes educational, social, and language background characteristics of our cohort stratified by test. Unfortunately, not all participants had data available on these measures, so the table does not include all participants who completed the tests. The majority of participants lived most of their lives and completed most of their formal education in their country of origin (rather than in the U.S.). Almost a third of the sample had to stop attending school to work, and approximately half of participants reported working for money during childhood. All but one of the participants reported that Spanish was the first language they learned. Average ratings of language used in various everyday activities indicated that Spanish was the predominant language used in daily life (with ratings for each activity ranging from 1 “Always in Spanish” to 5 “Always in English”, with 3 being “similarly in English and Spanish”). Nearly two-thirds of the sample was monolingual Spanish-speaking/strongly Spanish dominant, with the remaining third being bilingual. In addition to those self-report measures of language preference, the Controlled Oral Word Association Test (Borkowski, Benton, & Spreen, 1967; Gladsjo et al., 1999) was administered as an objective, performance-based measure of word fluency. Both the English

Table 2. Educational, Social, and Language Background Characteristics of the Normative Sample for the Grooved Pegboard and Finger Tapping Tests.

Characteristics	Grooved Pegboard (N = 254)		Finger Tapping (N = 183)	
	<i>M</i> (<i>SD</i>), %	<i>n</i>	<i>M</i> (<i>SD</i>), %	<i>n</i>
Educational Background				
Years of education in country of origin	8.53 (4.879)	227	8.41 (4.42)	170
Years of education in the U.S.	2.53 (4.73)	227	1.72 (3.45)	170
Proportion of education by country		227		170
More years of education in country of origin	84.14%	191	87.65%	149
More years of education in the U.S.	14.98%	34	11.18%	19
Equal number of years of education in both countries	0.88%	2	1.18%	2
Type of school attended [†]		243		181
Large	55.56%	135	51.93%	94
Regular	39.92%	97	43.09%	78
Small	4.53%	11	4.97%	9
Number of students in the class		247		181
Less than 21	15.39%	38	8.84%	16
21 to 30	39.27%	97	39.23%	71
31 to 40	24.29%	60	27.62%	50
40+	21.05%	52	24.31%	44
Had to stop attending school to work		224		180
Yes	28.57%	64	31.77%	54
Social Background				
Mother's years of education	5.76 (3.65)	180	5.76 (3.65)	180
Father's years of education	6.80 (5.06)	163	6.80 (5.06)	163
Years lived in country of origin	26.41 (12.50)	245	27.86 (11.87)	181
Years living in the U.S.	10.69 (10.85)	245	9.16 (9.56)	181
Childhood SES		251		182
Very poor	5.98%	15	6.04%	11
Poor	27.09%	68	26.37%	48
Middle class	58.17%	146	58.24%	106
Upper class	8.77%	22	9.34%	17
Worked as a child		248		181
Yes	52.82%	131	59.12%	107
Reason to work		130		112
Help family financially	38.46%	50	34.82%	39
Own benefit	61.54%	80	65.18%	73
Age started working as a child	12.98 (3.18)	127	13.41 (2.98)	106
Currently gainfully employed		224		179
Yes	68.75%	154	65.36%	117
Language				
First Language		250		180
Spanish	98.40%	246	98.89%	178
English	0.40%	1	0.00%	0
Both	1.20%	3	1.11%	2
Current language use rating*		251		181
Radio or TV	2.37 (1.03)	–	2.30 (1.01)	–
Reading	2.24 (1.18)	–	2.08 (1.11)	–
Math	1.54 (1.05)	–	1.41 (0.92)	–
Praying	1.26 (0.72)	–	1.17 (0.53)	–
With family	1.56 (0.90)	–	1.43 (0.74)	–
Performance-based language fluency [°]		203		170
Spanish dominant	62.07%	126	60.00%	102
English dominant	0.00%	0	0.00%	0
Bilingual	37.93%	77	40.00%	68

Note. *M*: mean; *SD*: standard deviation; SES: socioeconomic status.

[†]Types of school attended: Large = many classrooms per grade and room to play, Regular = at least one classroom per grade and room to play, Small = less than one classroom per grade.

*Current language use ratings: Via self-report questionnaires, participants rated their current language use for common daily activities, ranging from 1 (Always in Spanish) to 5 (Always in English).

[°]Performance-based language fluency: The Controlled Oral Word Association test was administered in English (FAS) and Spanish (PMR) to create an estimated English fluency rating from the ratio of scores.

Table 3. Mean, standard deviation, and range of the Grooved Pegboard and Finger Tapping total raw scores for dominant and non-dominant hands.

	N	Mean (SD)	Range
Grooved Pegboard Total Score (Dominant)	254	63.41 (11.47)	42–136
Grooved Pegboard Total Score (Non-dominant)	254	72.74 (12.72)	49–124
Finger Tapping Total Score (Dominant)	183	49.47 (6.79)	25.4–62.6
Finger Tapping Total Score (Non-dominant)	183	45.67 (5.91)	25.2–61.1

Table 4. Association between raw test scores and demographic characteristics.

	N	Age ^a	Education ^a	Gender ^b		<i>p</i>	Cohen's <i>d</i>
				Male	Female		
Grooved Pegboard Total Score (Dominant)	254	0.23*	−0.22*	64.73 (12.76)	62.48 (10.42)	.20	0.15
Grooved Pegboard Total Score (Non-dominant)	254	0.19*	−0.23*	73.71 (13.87)	72.05 (11.84)	.64	0.11
Finger Tapping Total Score (Dominant)	183	−0.09	0.35*	53.16 (5.75)	46.79 (6.23)	<.001	1.06
Finger Tapping Total Score (Non-dominant)	183	−0.14	0.27*	48.35 (5.67)	43.73 (5.32)	<.001	0.84

Note. Based on results from Pearson product moment correlation coefficients or Spearman ρ^a , and independent sample t-tests or Wilcoxon rank-sum tests^b. * $p < .001$.

version with letters F-A-S (Strauss, Sherman, & Spreen, 2006) and the Spanish version with letters P-M-R (Artiola i Fortuny, Hermsillo Romo, Heaton, & Pardee, 1999; Strauss et al., 2006) were administered to create an estimated English fluency rating from the ratio of scores [(FAS)/(FAS + PMR)] (Suárez et al., 2014). Participants with a ratio of scores $\geq .67$ (i.e. 2/3 of all words in English) were classified as English-dominant, and excluded from analyses. Participants with scores $\leq .33$ were classified as monolingual Spanish-speakers, and those in between were considered bilingual. See Suárez, Marquine, et al. (2020) for further detail.

There were no significant differences between participants tested in Arizona and California on any demographic factors in the overall cohort ($ps > .26$) or among participants from Cohort 1 ($ps > .16$). However, participants in Cohort 1 had significantly fewer years of education than Cohort 2 ($p < .001$), and analyses showed similar findings within participants from California only ($n = 152$; $p < .001$). This difference in years of education may be due to the specific recruitment goals for Cohort 1 to represent the full range of educational attainment (Cherner*, Marquine*, et al., 2020).

Raw scores to scale scores conversions

Table 3 shows descriptive characteristics of raw scores for the Grooved Pegboard and Finger Tapping total scores for dominant (Dom) and non-dominant (NDom) hands. Table 4 shows the univariable association of raw test scores with demographic variables. There were significant effects of education on both the Grooved Pegboard and Finger Tapping total raw scores (Dom and NDom), of age on Grooved Pegboard total raw scores, and large effects of gender (favoring men) on Finger Tapping total raw scores. There was a significant age and gender interaction on Finger Tapping NDom raw scores ($p = .03$), indicating that increasing age was associated with lower raw scores in males ($n = 77$, $p = .02$) but not in females ($n = 106$, $p = .67$). There were

Table 5. Raw-to-scale score conversions.

Scaled	Grooved Pegboard Raw Score (Dominant)	Grooved Pegboard Raw Score (Non-dominant)	Finger Tapping Raw Score (Dominant)	Finger Tapping Raw Score (Non-dominant)
19			65.0	64.9 – 65.0
18	< 47	< 51	62.4 – 64.9	60.2 – 64.8
17	47 – 48	51 – 52	61.8 – 62.3	57.2 – 60.1
16	49 – 50	53 – 56	61.4 – 61.7	56.6 – 57.1
15	51	57 – 58	58.8 – 61.3	54.3 – 56.5
14	52 – 53	59	57.8 – 58.7	52.8 – 54.2
13	54 – 55	60 – 62	55.5 – 57.7	50.7 – 52.7
12	56 – 57	63 – 65	52.9 – 55.4	48.8 – 50.6
11	58 – 59	66 – 68	50.6 – 52.8	46.6 – 48.7
10	60 – 62	69 – 71	48.6 – 50.5	44.5 – 46.5
9	63 – 65	72 – 77	46.5 – 48.5	42.5 – 44.4
8	66 – 68	78 – 80	44.5 – 46.4	41.1 – 42.4
7	69 – 72	81 – 87	41.6 – 44.4	39.0 – 41.0
6	73 – 78	88 – 94	40.1 – 41.5	38.1 – 38.9
5	79 – 91	95 – 104	36.6 – 40.0	36.7 – 38.0
4	92 – 107	105 – 108	32.2 – 36.5	32.6 – 36.6
3	108 – 119	109 – 118	25.8 – 32.1	25.8 – 32.5
2	120 – 225	119 – 220	1.1 – 25.7	1.0 – 25.7
1	226 – 301	221 – 301	0.0 – 1.0	0.0 – 0.9

no other significant two-way interactions among demographic variables on Finger Tapping or Grooved Pegboard raw scores.

Table 5 shows the raw-to-normalized scaled score conversions for the Grooved Pegboard and Finger Tapping Total Scores (Dom and NDom hands).

T-Scores equations

Table 6 shows the equations used to compute individual T-scores. As expected, the resulting T-scores had a Mean (M) of 50 and a Standard Deviation (SD) of 10 (Table 7). Similarly, for the subset of participants who had data on both tests, the Grooved Pegboard Dom hand T-scores had an M of 49.5 and an SD of 9.7, and Grooved Pegboard NDom hand T-scores had an M of 49.8 and an SD of 10.3. Pearson product moment correlations showed no significant effect of age or education on any T-scores ($p's > .96$), and there were no significant gender differences by t-tests ($p's > .97$), including when considering only participants who had data on both tests.

Group comparisons

Independent sample t-tests on Grooved Pegboard T-scores between Cohort 1 (Dom hand: $M = 49.49$, $SD = 9.66$; NDom hand: $M = 49.76$, $SD = 10.33$) and Cohort 2 (Dom hand: $M = 51.24$, $SD = 10.79$; NDom hand: $M = 50.54$, $SD = 9.15$) showed no significant differences ($p's > .23$). Similar analyses comparing participants who completed testing in Arizona ($n = 102$) and those who did so in California ($n = 152$) showed no significant differences on T-scores on the Finger Tapping test for either hand ($p's > .38$) or on Grooved Pegboard Dom hand T-scores ($p = .21$). There was a statistically significant difference on Grooved Pegboard NDom hand T-scores, such that T-scores were somewhat lower in Arizona ($n = 102$; $M = 48.39$, $SD = 10.36$) than California ($n = 152$, $M = 51.04$, $SD = 9.65$), $p = .042$, but with a small effect size (Cohen's $d = .27$).

Table 6. T-Score equations.

Measure	Equation
Grooved Pegboard Total Score (Dominant) ^a	$10^{*(SS \text{ Grooved Pegboard Dominant} - (-3.88528 - 22.03585 * \log(\text{age}/100) - 9.15441 * (\log(\text{age}/100))^2 + 1.66513 * (\text{edu}+1)/10 - 0.75294 * \text{gender}))/2.7217 + 50}$
Grooved Pegboard Total Score (Non-dominant) ^a	$10^{*(SS \text{ Grooved Pegboard Nondominant} - (10.48135 - 5.78302 * (\text{age}/100) + 1.61742 * ((\text{edu}+1)/10) - 0.48245 * \text{gender}))/2.86059 + 50}$
Finger Tapping Total Score (Dominant) ^b	$10^{*(SS \text{ Finger Tapping Dominant} - (6.07174 + 1.28165 * (\text{age}/100) + 2.21826 * ((\text{edu}+1)/10)^3 - 2.8893 * \log((\text{edu}+1)/10) * ((\text{edu}+1)/10)^3 + 2.85531 * \text{gender}))/2.46635 + 50}$
Finger Tapping Total Score (Non-dominant) ^b	$10^{*(SS \text{ Finger Tapping Nondominant} - (8.46996 - 3.043 * (\text{age}/100) + 1.58865 * ((\text{edu}+1)/10) + 2.20988 * \text{gender}))/2.6906 + 50}$

Note. ^aThese formulas should be applied to education level ranges from 0–20 and age 19–60. ^bThese formulas should be applied to education level ranges from 0–20 and age 20–55. Using values outside these ranges might result in extrapolation errors. Gender: Male = 1; Female = 0. Edu = years of education. Age = years of age.

Table 7. Comparisons of T-scores when raw data is normed utilizing different sets of norms.

Test Measure	N	Current Norms M (SD) Range	Non-Hispanic White Norms for English-speakers		Non-Hispanic Black Norms for English-speakers	
			M (SD) Range	Cohen's <i>d</i>	M (SD) Range	Cohen's <i>d</i>
Grooved Pegboard (Dominant)	254	49.98 (10.00) 25–82	51.28 (10.21) 19–83	−0.13*	58.52 (10.21) 27–91	−0.85*
Grooved Pegboard (Non-dominant)	254	49.98 (10.00) 21–77	47.31 (9.76) 21–73	0.27*	56.64 (10.76) 30–88	−0.64*
Finger Tapping (Dominant)	183	50.02 (10.02) 22–73	52.45 (8.87) 25–76	−0.26*	50.59 (7.81) 27–73	−0.06
Finger Tapping (Non-dominant)	183	49.99 (10.00) 20–73	53.95 (8.96) 29–74	−0.42*	51.45 (8.09) 28–73	−0.16*

Note. * $p < .0001$ based on dependent sample t-tests between T-scores based on current norms and non-Hispanic norms for English speakers.

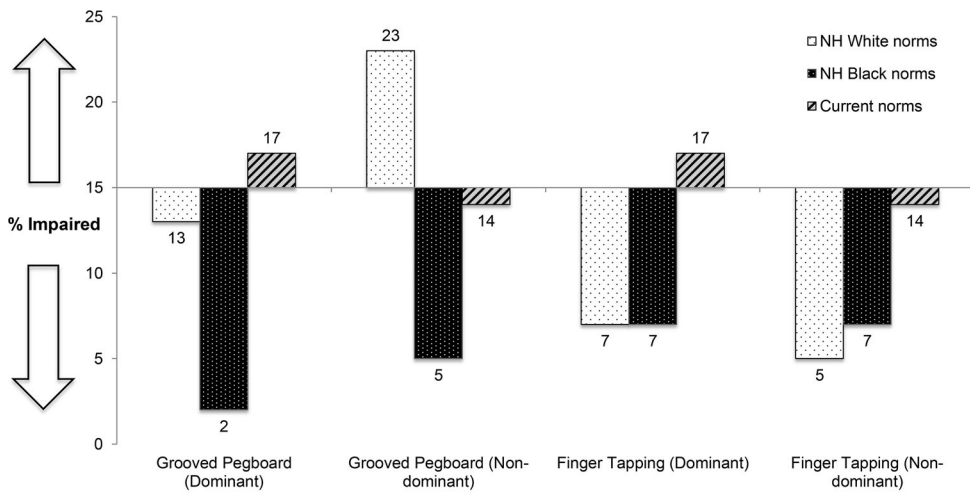


Figure 1. Rates of impairment on the current sample of Spanish-speakers based on published norms for English-speaking non-Hispanic (NH) Whites and NH Blacks (Heaton et al., 2004), and current population specific Spanish-speaking norms. Impairment was defined as T-score <40. Asterisks denote significant differences based on McNemar's test in comparison to rates of impairment based on Spanish-speaking norms; * $p < .005$, ** $p < .0001$.

Comparisons across normative sets

Table 7 shows T-scores based on the newly-developed norms for Spanish-speakers and T-scores when norms for native English-speaking NHWs and NHBs were applied to the current raw data. A series of dependent sample-tests showed that, compared to T-scores based on current norms, T-scores based on non-Hispanic norms were significantly higher (with generally large effect sizes) except for the following two instances: for Grooved Pegboard NDom hand, T-scores were lower when utilizing NHW norms, and for Finger Tapping Dom hand there were no significant differences when NHB norms were applied.

Figure 1 shows the percent of impairment classifications (using 1 SD cut-off) on the tests when the respective norms were applied. Results from McNemar analyses

showed that for most test scores, norms based on English-speaking NHWs and NHBs significantly underestimated rates of impairment in the current sample. The only exception was Grooved Pegboard Test NDom hand scores, for which NHW norms overestimated impairment.

To further explore possible reasons for the apparently anomalous finding that Spanish-speakers scored worse only on NDom Pegboard when NHW norms for English-speakers were applied, we examined the possible effects of dropping pegs on this test. Fifty percent of the Spanish-speaking participants (119 of the 238 with available data on drops) had at least one drop, and 41 had more than one drop (range = 2–11). Of those with drops, 23 individuals dropped pegs with both hands, 38 dropped only with Dom hand, and 58 dropped with only with the NDom hand; thus, more people had drops with the NDom hand (68% vs. 51% for Dom hand). Within the total sample, males were more likely than females to drop pegs on any trial (58% of males, 44% of females; $p = .036$), especially for NDom hand trials (43% vs. 28%; $p = .013$).

Individuals with drops on NDom hand trials had lower T-scores ($M = 47.85$, $SD = 9.93$) than those without drops on that trial ($M = 51.25$, $SD = 9.93$; $p = .012$), reflecting slower performance when drops occurred. To further investigate this finding, a matched pairs test was conducted at the individual level, comparing trials for individuals who dropped on one trial but not the other. The T-scores for trials in which pegs were dropped ($M = 48.64$, $SD = 10.09$) were significantly lower than T-scores for trials without drops ($M = 51.69$, $SD = 9.45$; $p = .003$), confirming that drops result in slower times.

Discussion

The present study aimed to develop normative data for commonly used tests of motor skills in a group of native Spanish-speaking adults in the U.S.-Mexico border region. The Finger Tapping and Grooved Pegboard tests have been previously normed in Spanish-speaking Colombian children (Rosselli et al., 2001), but the current study is the first to do so with adult Spanish-speakers in the U.S.-Mexico border region.

Findings from the present study of Spanish-speakers show small to medium effects of education on raw scores for both trials of the Finger Tapping and Grooved Pegboard tests. These education effects were lower than those reported in prior studies of NHW and NHB English-speakers (Heaton, Miller, et al., 2004). This discrepancy might be at least partly due to differences in education range and variability, and differential factors underlying years of education completed across ethnic/racial groups. While we do not have consistent data on access to education and/or reasons for terminating schooling, it is possible that lack of access and/or need to work at an early age notably contributed to discontinuing formal education at an early age for some in this sample of Spanish-speakers in the United States (Childfund, 2013; Cigna, 2016; Coley & Baker, 2013; Wolf, Magnuson, & Kimbro, 2017). Unlike much of the prior literature on the Finger Tapping test in which performance decreased with age (Bornstein, 1985; Da Silva et al., 2012; Villardita, Cultrera, Cupone, & Mejía, 1985), we generally found no significant effects of age, except for the NDom hand trial of Finger Tapping, in which performance was worse with increasing age in male individuals only. However,

the limited age range of our Spanish-speaking sample may account for the disparity. In our Spanish-speaking sample, males outperformed females on the Finger Tapping Test, which has been consistently demonstrated in the literature in both Spanish- and English-speakers on this test (Bornstein, 1985; Grice et al., 2003; Heaton, Miller, et al., 2004; Polubinski & Melamed, 1986; Pontón et al., 1996; Rosselli et al., 2001; Wang et al., 2015). In our sample, there were no gender differences on the Grooved Pegboard test raw scores. Although sex differences on Grooved Pegboard have not been found consistently in the literature, most studies on the Grooved Pegboard (and its variations) have reported that females outperformed males (Da Silva et al., 2012; Grice et al., 2003; Polubinski & Melamed, 1986; Rosselli et al., 2001; Wang et al., 2015).

When norms for English-speaking NHWs and NHBs were applied to our data of Spanish-speaking Hispanics, resulting impairment rates were largely lower for both tests, with the exception of the NDom trial for the Grooved Pegboard test. These results suggest that Spanish-speaking individuals from this population would have an increased risk of being incorrectly deemed “unimpaired” on these motor tests if existing norms for English-speakers are applied. Such applications of norms based upon other populations could lead to undiagnosed impairment in motor function. This could have significant clinical importance, since manual speed and dexterity are important for the performance of daily tasks and those involved in many occupations (Wang, et al., 2015); such skills may be especially needed in the kinds of manual jobs that tend to be most readily available in the U.S. for individuals with lower education levels and a lack of English proficiency (Childfund, 2013; Coley & Baker, 2013; Pandya, 2012). Loss of dexterity has been correlated with worse job proficiency, disease progression, and cognitive impairment (Bezdicek et al., 2014; Lundergan, Soderstrom, & Chambers, 2007; Price, 2014; Yancosek & Howell, 2009). In addition, the lack of appropriate motor evaluation and diagnosis may further increase the disparity in health outcomes that already exists between English- and Spanish-speakers (AHRQ, 2015; Cigna, 2016; Marquine et al., 2016; Martinez, 2008). For information regarding the clinical application of these norms and cognitive impairment in a population of individuals living with HIV in the U.S., see the paper by Kamalyan et al. (2020) in this issue.

Most prior research has demonstrated an over-classification of impairment when English-speaking norms were applied to Spanish-speakers (Casaletto et al., 2015; Cherner et al., 2007). That is, Spanish-speakers, similar to most other cultural minorities in the U.S., have typically been found to perform worse than English-speaking NHWs, although there are exceptions. For example, Hedden et al. (2002) found that Chinese participants located in China significantly outperformed North American participants located in the U.S. on verbal fluency and the Digit Span test, as well as multiple findings that East Asian American children exhibit better-developed motor skills (writing names and numerals) and more advanced mathematic abilities than European American children (Huntsinger, Jose, Liaw, & Ching, 1997; Zupei, Jose, Huntsinger, & Pigott, 2007). However, unlike the aforementioned assessments of motor skills that may benefit those with more formal education (e.g. paper-and-pencil tests), Pegboard and Tapping don't require skills learned in school, suggesting that all participants are equally unfamiliar with these tasks regardless of educational attainment. It has been suggested that speed is typically more valued in mainstream societies in the U.S., and

that individuals from less “competitive cultures,” such as the Hispanic/Latino cultures, may perform at a slower pace on neuropsychological tasks that require speed (Ardila, 2005; Ardila, Rodríguez-Mendéneez, & Rosselli, 2002; Ardila & Moreno, 2001; Arnold et al., 1994; Benson et al., 2014; Boone et al., 2007; Ojeda, 2010; Puente & Agranovich, 2003; Puente & Salazar, 1998; Rosselli & Ardila, 2003). In contrast, our data largely indicate the opposite for tests of fine motor skills; i.e. on those of the four speed-based scores considered here, the Spanish-speakers outperformed expectation based upon norms for English-speakers. The instruction of going “as fast as you can” for both the Grooved Pegboard test and Finger Tapping test might be sufficient to minimize the potential impact of cultural differences in any general value placed on speed. It might also be the case that different types of occupations (with more or less emphasis on motor speed) across racial/ethnic groups could be playing a role in current findings. While occupation data are not consistently available for the present sample, this may well be a relevant variable to consider in future studies investigating factors explaining differences in cross-cultural neuropsychological test performance.

It is unclear why the current sample of Spanish-speakers performed somewhat below expectations based upon published, NHW norms for English-speakers, only on the NDom hand trial of the Pegboard. The Pegboard test differs from the Tapping test in that it requires fine manipulation of small metal pegs, and therefore has the possibility of “errors” (dropped pegs). Our follow-up analyses revealed that pegs were more likely to be dropped by the NDom hand (especially by males), and that drops resulted in slower times on this test. Although individuals were excluded from the study if they had any self-reported significant hand or wrist injury, it is possible that more minor effects of prior injuries may have affected Pegboard performance. It is also quite possible that people in the current Spanish-speaking population (especially the males) had worked in manual-labor occupations more often than their better-educated, English-speaking counterparts who contributed to the published norms for NHWs. It has been suggested that non-dominant hands and fingers are more prone to injury when working with tools with one’s dominant hand while using the non-dominant hand to maintain the object being manipulated. This could increase the risk of hand or finger injuries on the non-dominant hand, such as being smashed while hammering a nail, or a finger being cut while preparing food. Therefore, such workers could potentially incur decreased dexterity due to minor finger injuries from years of working with their hands, also relating to more drops with non-dominant hands. Unfortunately, we do not have specific information about the manual requirements of jobs our participants have held, so this remains a speculative (albeit plausible) possibility.

Collecting data on minor hand/finger/joint abnormalities or disabilities could help confirm our speculations in future normative studies of motor function. Additionally, including an assessment of grip strength could contribute to other mechanisms. For example, it has been suggested that the grip strength of the dominant hand of healthy adults averages 10% greater for the dominant hand, potentially due to higher resistance to fatigue than the non-dominant hand (Farina et al., 2004; Harris & Eng, 2006). Multiple studies have found differences in hand dominance and function to be relevant in the assessment of orthopedic and neurological conditions, including lateralized brain damage (Mack, 1969). Harris and Eng (2006) described clinical findings

in Osteoarthritis (Caspi et al., 2001) and Parkinson's Disease (Nutt et al., 2000), in which functional changes related to hand dominance. Bravi et al. (2017) described studies in the literature suggesting that precision and variability of movements in tasks of timing coordination were related to somatosensory feedback (Spencer, Zelaznik, Diedrichsen, & Ivry, 2003). Hammond (2002) explored the functional interplay of motor lateralization and structural brain asymmetries, often correlated with handedness, highlighting further clinical implications related to motor function. Bagesteiro and Sainburg (2002) suggested that the dominant arm is better at predictive and dynamic features of movement, while the non-dominant arm is specialized for stabilizing tasks.

Another unexpected finding about our sample's NDom hand performances on Pegboard is that there was a small Arizona versus California site effect only on this trial of this test: the Arizona cohort had somewhat lower T-scores on the current norms than the California cohort ($p = .042$, Cohen's $d = .27$). Although the prevalence of peg-dropping was not different at the two sites, the site difference in speed-based T-scores disappeared when NDom trials with peg drops were excluded. Again, while peg dropping appears to importantly affect results on this test, we are limited by inadequate information about participants' work histories and prior hand injuries. Future examinations using this test should more carefully inquire about such histories, especially for interpreting the meaning of peg drops and associated time penalties.

Normative data for Spanish-speakers along the U.S.-Mexico border region were successfully generated, but it is worth noting that a majority of the study participants lived in California and not other border states. However, California continues to have the largest population of Hispanics in the U.S., and 63% of all Hispanics in the U.S. are of Mexican origin/descent (Flores, 2017; U.S. Census Bureau, 2017). Another limitation is that we do not have consistent information about potentially important aspects of participants' backgrounds, such as levels of acculturation, country of origin, and occupation, among others. Only a subset of participants have data related to acculturation and bilingualism available, and in this subsample, we investigated the association of these factors with test performance in Suárez, Marquine, et al. (2020). Additionally, our sample does not include Spanish-speaking adults over the age of 60 years old (55 years old for the cohort with data on the Finger Tapping test), and thus the current norms should be used with great caution (if at all) with Spanish-speakers over age 60.

Normative standards from other groups are not a good fit for interpreting motor test performance in the Spanish-speaking population, which in the current instance would have increased risks for misdiagnosing fine motor impairment. These findings underscore the importance of appropriate, population-specific normative data, even for tests of motor ability that have a minimal verbal/linguistic demand. Despite the study limitations, these norms have clinical relevance and the potential to improve patient care through more accurate diagnostic evaluation of U.S.-Mexico borderland Spanish-speakers. However, due to our modest sample size, lower age range, and limited data on cultural background information, these norms should be considered specific to the young to middle-aged, Spanish-speaking, adult population in the U.S.-Mexico border region of California and Arizona. Additional studies are warranted to assess generalizability of these findings in similar populations and extend to more diverse Spanish-speaking groups in the U.S. Also, the data on which the current norms are based were collected 10

to 20 years ago. Since we do not have more current data for Spanish-speakers on these tests, we cannot examine whether there may be a Flynn or cohort effect with individuals from present day. However, when significant differences between the current cohorts (tested 10 years apart) were investigated in another paper in this issue (Cherner*, Marquine*, et al., 2020), few were found, and there were no statistical differences between cohorts on Pegboard T-scores (Tapping data from Cohort 1 only). Nevertheless, due to the length of time since these studies ended, revalidation of these norms with more contemporary data would be needed to clarify or rule out any generational effect. Further research also is needed to better understand the many factors that may influence test performance between different populations, particularly in the diverse and heterogeneous Spanish-speaking population, where differences exist regarding country of origin, acculturation status, educational background, and linguistic preference/fluency. While we have some “culturally-relevant” data available for our normative sample, their associations with neuropsychological performance will be investigated in an upcoming paper. Due to the complexity of the interactions of educational and social characteristics with both corrected and uncorrected scores, the significant associations of these background characteristics with domains in this NP-NUMBRS issue will be described in a separate, upcoming paper. Such insights with these and other tests are likely to be important for informing clinical evaluations and for improving overall health outcomes for Spanish-speakers in the U.S.

For more information on the NP-NUMBRS norming project and next steps, see the paper by Rivera Mindt*, Marquine*, et al. (2020). Also, for the interested reader a user-friendly digit calculator will be available for clinicians to generate T-scores for the Grooved Pegboard and Finger Tapping tests to implement in the assessment of motor function based on the current new norms for this particular population.

Disclosure statement

All authors attest that there are no conflicts of interest with this work.

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Appendix A

Grooved Pegboard instructions

“Aquí tenemos un tablero con unas ranuras y estas son unas clavijas.”

The examiner points out each and then picks up one of the pegs and continues.

“Todas las clavijas son idénticas. Todas tienen un lado plano y un lado redondo, igual que las ranuras del tablero. Lo que usted debe hacer es colocar correctamente el lado plano de la clavija con el lado plano de la ranura y colocarlas en el tablero así.” (insert first row of pegs.)

Start with their dominant hand

DOMINANT HAND:

“Cuando yo diga “Adelante” comience aquí (point to the top left groove) y coloque las clavijas en el tablero lo más rápido que pueda, usando solamente su mano derecha. Llene la hilera de arriba completamente de este lado a éste. No deje de llenar ninguna ranura, y llene cada hilera de la misma manera en que completó la primera. ¿Alguna pregunta? ¿Listo/a? Lo más rápido que pueda. Adelante.”

NON-DOMINANT HAND:

“Cuando diga “Adelante” comience aquí (point to the top right groove) y coloque las clavijas en el tablero lo más rápido que pueda, usando solamente su mano izquierda. Llene la hilera de arriba completamente de este lado a éste. No deje de llenar ninguna ranura, y llene cada hilera de la misma manera en que completó la primera. ¿Alguna pregunta? ¿Listo(a)? Lo más rápido que pueda. Adelante.”

Discontinue test if subject cannot complete task in 301 seconds (5 minutes, 1 second).

Appendix B

Finger Tapping instructions

“Ahora vamos hacer un examen para ver que rápido puede dar palmaditas.”

The examiner demonstrates the use of the key.

“Ahora vamos hacer un examen para ver que rápido puede dar palmaditas. Usaremos esta llavesita (demonstrate the use of the key to the subject) y quiero que dé palmaditas lo más rápido que pueda usando el dedo índice (point to the forefinger of the subject) de su mano (derecha/izquierda). Cuando lo haga, asegúrese usar no más que el dedo. No mueva su mano entera o su brazo. Cuando dé palmaditas, recuerdese que la llave tiene que subir para arriba y dar golpear cada vez o el número no cambiará.”

The examiner demonstrates how the key operates and how it should be allowed to "click" etc.

“Ahora, mueva la tabla a una posición que sea cómodo para su mano y practique”

After a brief practice period:

“Recuerdese de hacerlo lo más rápido que pueda. ¿Entiende? ¿Listo/a? ¡Empiece!”